California Department of Water Resources | Bay Delta Office | **Delta Modeling Section**

DMUG

Delta Modeling User Group

NEWSLETTER | 2017

CONTENTS

PROJECTS UPDATE

DMUG PEOPLE

2017 Annual Report

Min Yu, Senior Engineer WR, DWR

The following are brief summaries of modeling work conducted during 2016, which are presented in the 2017 Annual Report to the State Water Resources Control Board. The report is available online at [http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/AR2017/AR-2017-all.pdf.](http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/AR2017/AR-2017-all.pdf)

Chapter 1 | Evaluation of the Recalibrated Martinez Boundary Salinity Generator with DSM2 Version 8.1

The Martinez boundary EC (electrical conductivity) generator for planning studies or forecasting was first developed by the Delta Modeling Section in 2001 (Ateljevich 2001), which was based on the original antecedent flow-salinity relations model, generally referred to as G-Model (Denton and Sullivan 1993), and incorporated tidal variation effect. The Martinez EC generator was recently recalibrated by using PEST, which is mathematically based calibration software (Sandhu and Zhou 2015). This chapter documents the effects of this recalibrated Martinez EC generator on planning studies. The Bay Delta Conservation Plan (BDCP)/California WaterFix simulations using Delta Simulation Model 2 (DSM2), version 8.0.4, during a 16-year planning simulation, 1974–1991, were converted to DSM2 version 8.1 with North American Vertical Datum of 1988 (NAVD88). We (Liu, Zhou, and Sandhu) will refer to the original Martinez EC Generator (Ateljevich 2001) as the Old Generator and the recalibrated Martinez EC Generator as the New Generator (noted as NG in figures). The simulation results were compared with the original results computed for BDCP by using DSM2 version (v)8.0.4. Studying the incremental differences in results between the two versions of DSM2 may reveal whether those differences would significantly affect or change any analysis conclusions in the simulations previously computed for BDCP by using DSM2 v8.0.4.

Chapter 2 | DSM2 Nutrients Modeling Sensitivity Analysis

The California Department of Water Resources' Delta Modeling Section is developing a new Delta Simulation Model 2 (DSM2) transport module, called the General Transport

Model (DSM2-GTM). Progress on this effort was previously reported in Hsu et al. (2014). When the model development is completed, DSM2-GTM will include sediment, dissolved oxygen (DO), and mercury cycling modules to simulate non-conservative constituents.

Part of the DSM2-GTM development process is to calibrate the DO module that simulates the transport and reaction of water temperature and nine non-conservative constituents that are currently included in the DSM2-QUAL computation. These nine constituents are DO, nitrate (NO3), nitrite (NO2), ammonia (NH3), organic nitrogen (Org-N), carbonaceous biochemical oxygen demand (CBOD), ortho-phosphate (PO4) assumed to represent dissolved phosphorus, organic phosphorus (Org-P), and algae. In general, there are two types of model calibration approaches – automatic and manual. If the manual calibration approach is used to carry out the DSM2-GTM calibration, choosing which constituent reaction rates to more efficiently calibrate the model could be challenging. To have a better idea regarding which constituent reaction rates may possess more significant effects on the model results, a sensitivity analysis was performed to test how the model results respond when changing certain constituent reaction rates. This chapter summarizes the sensitivity analysis approach and preliminary findings to date. This sensitivity analysis is an initial investigation and is also an on-going exercise along with the DSM2-GTM development.

Chapter 3 | Implementing DETAW in Modeling Hydrodynamics and Water Quality in the Sacramento-San Joaquin Delta

Numerical modeling of the hydrodynamics and water quality in the Sacramento-San Joaquin Delta channels requires accounting for in-Delta net channel depletion because of agricultural diversions, including seasonal leaching, seepage from channels to Delta lowland islands, riparian and native vegetation evapotranspiration, and evaporation from free-water surfaces. The California Department of Water Resources has recently developed a new model, the Delta Evapotranspiration of Applied Water Model (DETAW v2.0), which is a significant improvement over current methods for estimating Delta consumptive use and net channel depletion. This chapter presents the key aspects of DETAW v2.0 and its implementation in the detailed modeling of Delta conditions.

Chapter 4 | Delta Salinity Simulation with SCHISM

This chapter is excerpted from Shu and Ateljevich (2017) and summarizes 3D hydrodynamic modeling performed by the California Department of Water Resources' Bay-Delta Office (BDO) to assess flow patterns and transit time in the Clifton Court Forebay

(Forebay). The motivation for this work comes from the National Marine Fisheries Service 2009 Biological Opinion, Action IV.4.2 (National Marine Fisheries Service 2011), which prescribes limits on pre-screen losses of salmonids and steelhead in the Forebay and obliges DWR to study methods to reduce this loss. This report focuses on model development that has been completed and a study based on this model of how transit time across the Forebay responds to various filling and dredging actions. The premise underlying this investigation is that fish will benefit from faster transit which reduces their exposure to predators.

DSM2 Calibration Status

Lianwu Liu, Engineer WR, DWR

Project Description: A new and extensive calibration of DSM2 is being planned with the objective of improving model simulation of historical Delta EC conditions. Recent years of model application have pointed to areas where improvements are needed. Of particular interest is the latest multi-year drought. In addition, a new DSM2 grid has been generated based on the latest DEM and a new consumptive use model (DETAW) is replacing the current model, DICU. Tasks underway or planned are described below.

Data Collection: Acquire and assess the latest available hydrodynamic and water quality data in the Delta.

Observed data from past and recent years were collected from different sources for the purpose of this new calibration of DSM2. Data sources included United States Geological Survey (USGS), DWR's Water Data Library (WDL), United States Bureau of Reclamation (USBR), DWR's California Data Exchange Center (CDEC), and Interagency Ecological Program (IEP).

We created a GIS coverage with the Delta monitoring stations from various agencies. Each station has a unique station ID from its operating agency. Scripts created by the Delta Modeling Section staff were used to download all the data on the list from various web sites and convert the data into a DSS file. In the DSS files, each station is identified by a Location ID using the RKI method (Part B), agency/station ID (Part F), a descriptive name (Part A) and data range (Part D). Thus the DSS file is self-descriptive with information of the location, descriptive name, data source, and data range. DSM2 output was also identified by these Location IDs. This makes quite convenient comparing model output with observed data at each location.

The downloaded data was screened by a python script to eliminate errant values. The script also uses a median filter to eliminate data which fall outside a conceivable range. This filter was used very cautiously, in order to avoid eliminating valid data. When in doubt, values were retained. Visual inspection was done to compare before/after screening to make sure no good data were eliminated.

DETAW Integration: review and integrate DETAW into DSM2 simulations.

Work is underway to use DETAW-based consumptive use to refine channel depletions. Preliminary calibration showed significant improvements in modeling Delta EC, especially during dry years and drought periods.

Improvement of Hydro: The DSM2 grid has been refined and cross-sections have been regenerated using a newly developed GIS tool and the latest DEM (Chapter 2 of the 2016 Annual Report). Extra channels have been added to better represent the natural channels. The GIS tool leverages ArcMap functionality to provide a robust and complete working environment to view and edit DSM2 channels, nodes, and cross-sections.

The open water area algorithm has been modified to include changing bathymetry with changing elevations. Previously, open water areas were treated as a constant area with a bottom elevation. This change will help to better model Liberty Island and other open water areas in the Delta (Chapter 2 of Annual Report 2015)

Other improvements under consideration include updating the Clifton Court gate equations as referenced in Chapter 6 of Annual Report 2015 and improving the modeling of the hydrodynamics in Franks Tract.

Calibration Metrics Plots: Improve tools and methods for assessing model skills.

Python scripts will be updated to replace Microsoft Excel Macros which currently are used to generate calibration metrics plots.

A new animation tool has been developed by Nicky Sandhu (http://dsm2web.water.ca.gov). This tool can be used to see animation of model results, e.g. EC, using a 2-D view of the whole Delta. It may help understand the big picture of the Delta and improve the model.

Automated Calibration with Pest: Investigate use of automated calibration tools such as PEST to reduce calibration time and improve the final product.

PEST has been utilized for a preliminary Hydro calibration with the new grid using the approach described in DSM2 Newsletter 2016. We will continue to refine the Hydro calibration and test for an EC calibration.

Planning Study

Improvements related to modeling planning studies include updating the astronomical tide generator and recalibrating the Martinez EC generator (Chapter 7 of Annual Report 2015).

Estimating the 2016 Delta Crop Idling Impact on the Delta Evapotranspiration by DETAW v2.0

Liang Lan, Engineer WR, DWR

In 2017 the SWRCB, the Office of the Delta Watermaster and the Center for Watershed Sciences at UC Davis initiated a process to evaluate the impact of crop idling in 2016 on Delta crop evapotranspiration (ETc). This study is based on Delta land use surveys in 2015 and 2016 and the application of seven different models by various participants. One element of this study consisted of comparing results from all seven models to available field-measured ETc. The Delta Modeling Section participated in the study by providing ETc estimates based on applying DWR's model Delta Evapotranspiration of Applied Water, version 2.0 (DETAW v2.0) to 2015 and 2016 conditions. This brief report summarizes the process of applying DETAW v2.0 and presents key results.

An independent consulting firm Land IQ, Inc. (LIQ) provided land use survey maps for 2015 and 2016 with 31 land use classes. Since DETAW v2.0 only has 15 land use classes, some land use classes by LIQ were aggregated in DETAW v2.0. In addition, the land use surveys for 2015 and 2016 did not include sugar beet and non-irrigated grain, which are part of DETAW v2.0's 15 classes. Therefore, DETAW v2.0 only calculated the ETc for 13 land use classes in 2015 and 2016.

DETAW v2.0 first estimated the reference ET (ETo) for each of the 168 subareas in the Delta by using Hargreaves- Samani method with a spatial correction based on CIMIS ETo. The ETc for each of 13 land use classes and 168 islands then were calculated as the product of the estimated ETo and the crop coefficient.

The DETAW v2.0 analysis is based on several important assumptions: 1) fallowed lands are treated like native vegetation for consumptive use rates, 2) native vegetation in Delta Lowlands has sufficient water supplies without irrigation, 3) reduced crops,

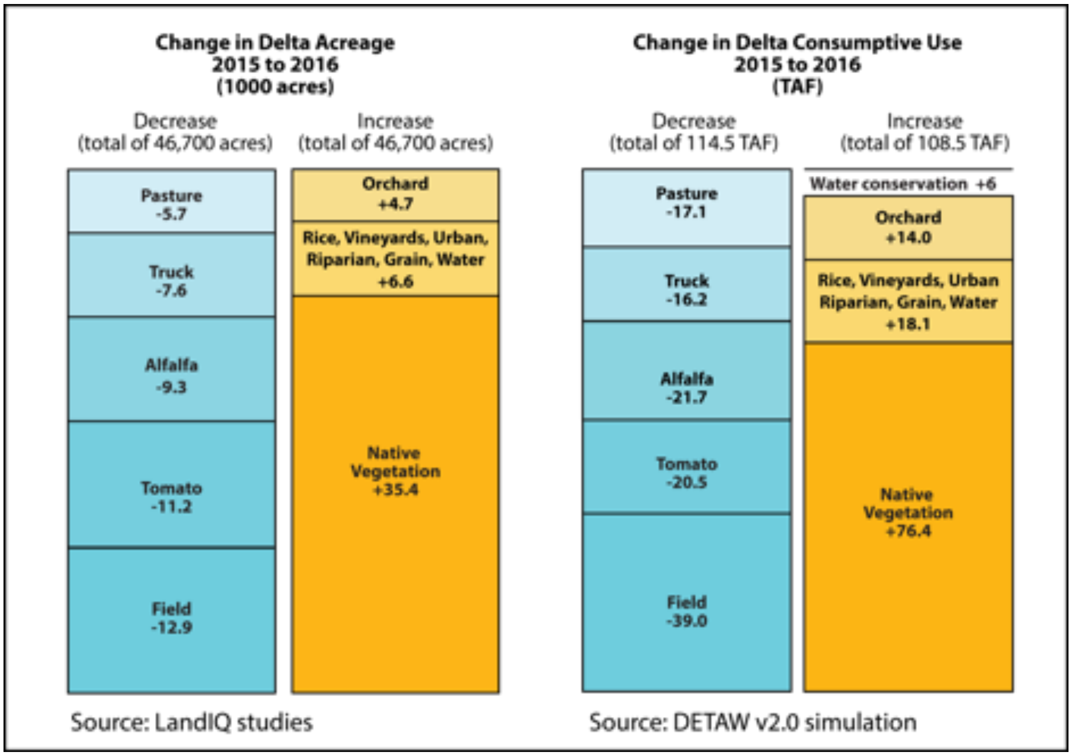


Figure 1. The differences in DETAW v 2.0-estimated ETc during the irrigation seasons of 2015 and 2016 due to the differences in land use.

corn, tomato, and alfalfa are harvested before the end of the irrigation season, and 4) native vegetation consumes more water during the non-irrigation season than does harvested land.

Figure 1 shows the differences in DETAW v 2.0 estimated ETc during the irrigation seasons of 2015 and 2016 due to the differences in land use for these two years. The land use changes in 2016 include decreases in field, tomato, alfalfa, truck and pasture, and increases in native vegetation, orchard and other crops, compared to the land use in 2015. The fallowed lands and corn listed by LIQ were taken to be in DETAW v2.0 native vegetation and field respectively. The major land use decreases mostly correspond to the increase of fallowed lands. These fallowed lands, while not receiving irrigation, still consume water. Based on the analysis of simulation results, DETAW v2.0 estimated ETc fallow to be 2.0 ft during the irrigation season which is relatively less than that of field (2.4 ft), alfalfa (3.0 ft), truck (2.4 ft), and pasture (3.0 ft), and similar to that of tomato. Therefore, it is not surprising that the 35,400 acres increase of fallow lands in 2016 causes an ETc increase of 76.4 TAF, while the similar acreages (35,500 acres) of land use decreases of corn, alfalfa, truck and pasture results in an ETc decrease of 94 TAF. According to DETAW v2.0, fallowing lands in 2016 conserved about 18 TAF of water. However, 2016 also experienced and increase in land use for Orchard, Riparian, Rice, and water body, which body, which together consumed much more water than the fallowed lands and even some regular crops. The estimated total Delta ETc during the irrigation season in 2016 (1686 TAF) was only 6 TAF water less than that for 2015 (1692 TAF).

The total Delta ETc for water year 2016 (2235 TAF) is estimated to be about 50 TAF higher than that in 2015 (2185), mostly because the increased fallow lands in 2016 consumed 122 TAF more water. DETAW 2.0 indicates that crop idling as in 2016 may not save water of the water year, although it can saves water during the irrigation season.

As mentioned before, the analysis above is based on the key assumption that the consumptive use in fallowed lands is the same as for native vegetation. If the fallow lands were taken as the bare soil, the results should be much different. All the increased fallow lands in 2016 were located in Delta Lowlands. Lowlands have enough subsurface water or seepage, so the native vegetation assumption should be reasonable. However, field measurements are required to confirm this assumption.

Martinez Planning Tide Generation

Ines Ferreira, Engineer WR, DWR

Introduction

The Delta Modeling Section maintains a DSM2 "Martinez planning tide" for use as a boundary condition in planning studies. The planning tide methodology produces estimates that closely match historical values during recent years, but that can be extended back appropriately as far back as a century where these values are unavailable or inappropriate. The planning tide includes three parts: an astronomical or harmonic component, a subtidal component due to seasonal and weather events, and a detrending component that compensates for past sea level rise.

Our immediate motive for revising the planning tide at Martinez was to update the flow-salinity relationships ANN used in CalSim 3 for existing conditions and to provide boundary conditions for associated planning studies in DSM2. Although current CalSim 3 runs from 1921 to 2015, its salinity relationships were derived from an earlier ANN training based on a shorter observed data record.

To update the flow-salinity relationships in CalSim 3, the following steps are required:

- Generate planning tide at Martinez
- Use Martinez planning tide as DSM2 boundary condition to generate EC throughout the Delta
- Retrain the salinity ANN used in Calsim 3 with new flow and salinity values from DSM2

In this newsletter we report on the first of these steps. The methodology described here is mostly the same as that used by Ateljevich (2001, 2007). There are two major differences. First, we have changed tidal analysis tools. We now work with VTide, which is based on Foreman (2007). This should enhance openness, as we are now in the midst of packaging tools for the creation of the planning tide as a tutorial. Second, relative to the last effort

[2] VTide is a re-implementation of Mike Foreman's Versatile Analysis program (Foreman et al., 2007). A copy is distributed along with Bay-Delta SCHISM and it will be made available as a standalone tool shortly.

With a longer record at our disposal, we were able to include more harmonic constituents and assess whether or not additional harmonic constituents could improve cross-validation prediction error.

there is currently a longer common period of record for San Francisco and Martinez water elevation records. With a longer record at our disposal, we were able to include more harmonic constituents and assess whether or not additional harmonic constituents could improve cross-validation prediction error.

The steps that go into generating the Martinez planning tide are as follows:

1. Compute astronomical tides at San Francisco and Martinez (ASTRO)
   i. Download observed water elevation and qa/qc data
   ii. Determine harmonic constituents with VTide , possibly masking high flow
   iii. Predict astronomical tide with VTide over full period
2. Estimate subtidal water level fluctuations at Martinez (SUBTIDE)
3. Evaluate the standard NOAA sea level trend for San Francisco over the planning period (TREND)
4. Compute new planning tide as PT = ASTRO + SUBTIDE – TREND.

1. Computation of Astronomical tide at San Francisco and Martinez (ASTRO)

In tidal analysis, some of the harmonic constituents (frequencies) of interest are so close together that it takes a fairly long record to identify them individually. Additionally, beyond the notion that longer is better there are some standard periods (one year, 19 years etc) called synodic periods that are preferred for differentiating neighboring frequents. Currently available water elevation data at San Francisco and Martinez encompass a common period of approximately 26 years (1991-2017). This is an ample record, including not only the 19-year synodic (the longest normally used) with some leftover years out for cross-validation.

Theoretically, hundreds of constituents can be computed with a 19 year data set. However, we follow more routine practices that start with a menu of 30-60 main candidates are analyzed, lumping smaller nearby satellites as "node adjustments" to the main frequencies. This makes for a much simpler to describe procedure, and the results are insensitive to the treatment of satellite frequencies.

For purposes of tidal estimation, we downloaded San Francisco hourly water elevation data from NOAA for 1/1/1990 to 4/30/2017. Martinez 15-minute data wfor 1/26/1991 to 4/26/2017 were obtained from DWR Division of Environmental Services and representsa QA/QCd version of the station reported as MRZ on CDEC.

The period of 6/1/1991 to 12/31/2009 was used for the harmonic analysis for both locations. We started the analysis on June 1 to exclude the freshet which occurred earlier that year. We did not use the current NOAA tidal epoch, which is earlier, because Martinez data is not available for the entire 19-year period. Some years after 2009 were used, individually, for validation.

We cleaned observed stage data by filtering outliers and identifying shifts due to timestamping errors. VTide was then run to analyze the data and predict the astronomical tide, with some adjustment of constituent choices based on amplitudes and statistics of the constituent estimates. These estimates tend to favor over-fit, and we wanted to know the sensitivity of tidal prediction error some years later, particularly roughly half a lunar nodal cycle after the analysis period.

For the purpose of identifying which constituents should be included in the astronomical tide prediction, we started with 68 constituents that can be separated with an eight-year (or longer) observation record. The vtide_analyze program was used to calculate constituents and associated statistics. Constituents with the smallest t test P-values were progressively eliminated from the analysis. At that point we compared RMSE for each 19-year analysis from the least squares fit. These are shown under 1991–2009 column in tables 1 and 2 for San Francisco and Martinez, respectively.

The difference in the computed RMSE for VTide runs which include 35 or more (suitably selected) constituents is negligible. We elected to use the analysis which identified 39 harmonic constituents, a number that was chosen more on the basis of Martinez than of San Francisco.

The fitting of harmonic constituents to the 19-year period is the calibration step, while the validation step is the comparison of the prediction fit for individual years outside the calibration period. For the validation step, tide predictions were made for some years after 2009. RMSE for the validation step are shown on Table 1 for years 2011, 2013, and 2014, years in which there are observed data at both San Francisco and Martinez. The computed RMSE values for those years are similar to the RMSE for the calibration period of 1991-2009, confirming that the tidal predictions are robust in years outside the calibration.

Another more focused test of performance was obtained by comparing the RMSE of the data after applying a high pass filter on predicted and observed datasets. The reason we do this is to focus on the tidal frequencies, which are the only ones we can really addresswith a tidal analysis. When astronomical tide is compared to observed tide, the error statistics eventually get dominated by contributions from subtidal variation, which we have no hope of estimating well because they are season

	Predicted Tide				High Pass Filtered			
	2011	2013	2014	1991–2009	2011	2013	2014	1991–2009
68	0.25	0.24	0.34	0.30	0.10	0.07	0.08	0.10
39	0.25	0.24	0.34	0.30	0.10	0.08	0.08	0.10
NOAA	0.25	0.22	0.33	0.31	0.11	0.08	0.08	0.11
35	0.25	0.24	0.34	0.30	0.10	0.08	0.08	0.11
10	0.29	0.28	0.36	0.34	0.18	0.158	0.16	0.18

Table 1. San Francisco Tide Predictions RMSE (feet)

and weather-dependent. Applying a high pass filter eliminates this component of the tide so we can isolate error in the harmonic part of the fit.

As shown in Table 1, the high pass filtered data RMSE is small – about one-third – of the corresponding RMSE for the unfiltered prediction. It follows that in terms of the overall procedure we are at the point of decreasing returns on the harmonic component, and that the remaining misfit is dominated by low frequency events, which will be addressed next section. The RMSE for individual validation years outside the calibration period is consistently lower than the RMSE for the calibration period (1991-2009)–this is a curious kind of "super performance" on validation data that we don't think should be counted on to hold in the future. Table 1 also confirms that paring the original 68 constituents down to 35 did not increase cross-validation error.

Table 2 is a similar table to Table 1 but contains results for Martinez. Unsurprisingly, the tide prediction RMS errors for Martinez are slightly higher than those for San Francisco. That is to be expected, as water elevation at Martinez is more influenced by shallow water and frictional effects than at San Francisco. As with San Francisco tide prediction, we chose to use 39 constituents for the CalSim work.

2. Subtidal adjustment at Martinez (SUBTIDE)

Harmonic methods do an excellent job at replicating the diurnal and semidiurnal

Table 2. Martinez Tide Predictions RMSE (feet)

	Predicted Tide				High Pass Filtered			
	2011	2013	2014	1991–2009	2011	2013	2014	1991–2009
68	0.33	0.28	0.37	0.35	0.13	0.11	0.12	0.13
39	033	0.29	0.37	0.35	0.13	0.12	0.13	0.14
35	0.33	0.29	0.37	0.36	0.14	0.13	0.13	0.15

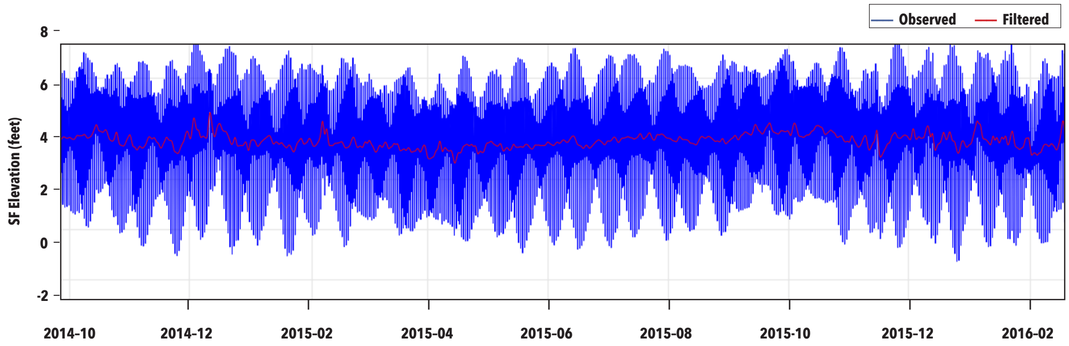


Figure 1. San Francisco Observed and Filtered Tide

components of the tide, but they do not include a realistic depiction of longer term variation at subtidal scales, including synoptic-scale weather events and seasonal variation. An example of subtidal variation is shown for San Francisco in Figure 1 as filtered tide (40 hours). We model Martinez subtidal variation based on historical values at San Francisco, a station that has a very long record.

Once the astronomical tides at San Francisco and Martinez (ASTRO) are computed, the residual (observed minus astronomical) tide at both locations is calculated.

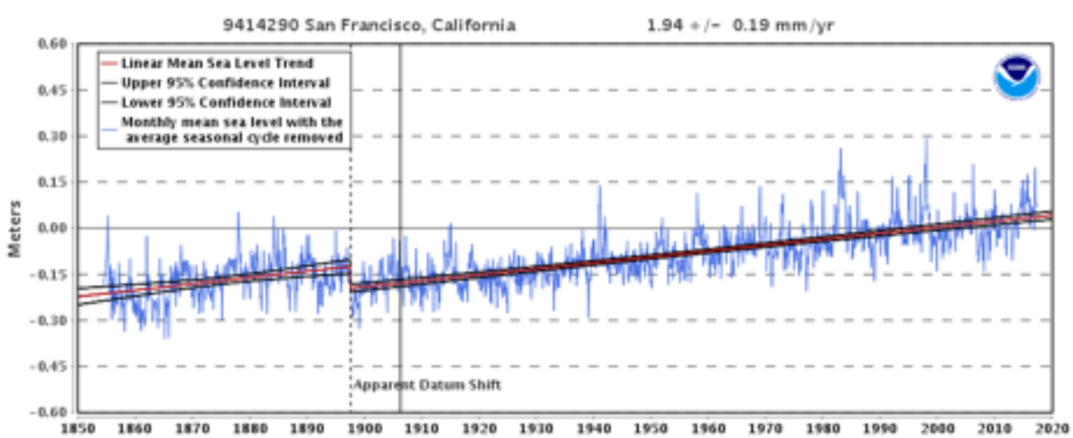
Gaps in the observed data are filled by linear interpolation of the smoothed time series. The gaps in the original San Francisco residual time series are then filled with values obtained by interpolating the smoothed values to obtain z'_{sf}, the hourly residual at San Francisco.

The Martinez residual estimate is computed as the average of the previous two hours of the San Francisco time series (Ateljevich 2001).

$$z'_{mrz}(t) = 0.50\,[z'_{sf}(t-1) + z'_{sf}(t-2)]$$

where z'_{mrz} is the hourly estimated residual at Martinez, and z'_{sf} is the hourly residual at San Francisco.

Figure 2. San Francisco Sea Level Trend (NOAA) .



Hourly z'_{mrzw} is then interpolated to obtain a Martinez residual at a 15-minute interval. This is what we called SUBTIDE in the introduction.

3. Creating the sea level rise TREND time series

The last adjustment to the Martinez planning tide is to correct for historical sea level rise. Sea level rise trend at San Francisco was obtained from NOAA, and is depicted in Figure 2. The intercept (time defined as zero nominal sea level rise) is May 1, 1998, close to the center of our analysis. The subtidal adjustment is fairly minimal for the decades before and after 1998, but the adjustment "lifts" the early part of the record by 15 cm so that sea level throughout the record is pegged to 1998.

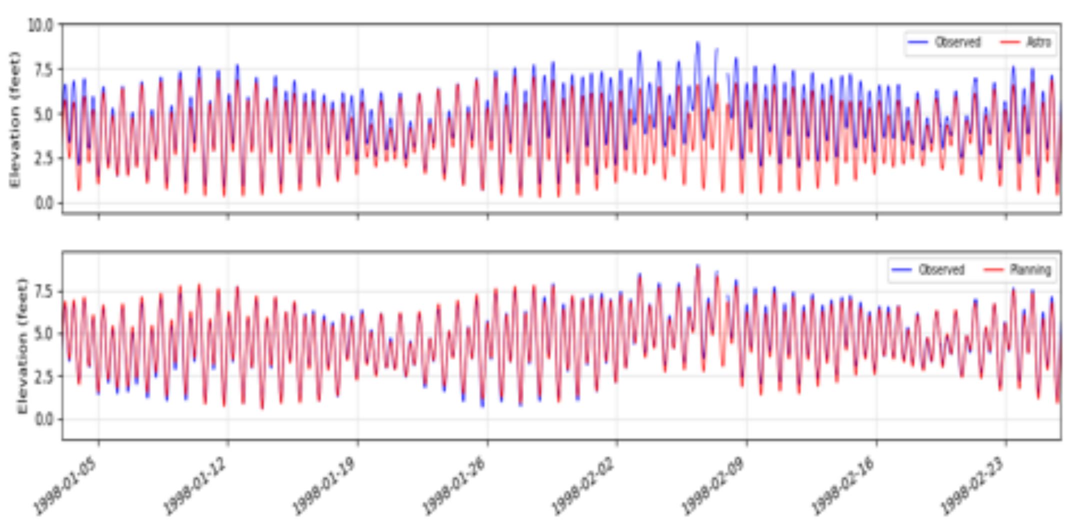
4. Computing Martinez planning tide (PT)

The last step in the derivation of a planning tide (PT) at Martinez is to add to the astronomic tide at Martinez, the subtide and subtract the sea level rise trend.

PT = ASTRO + SUBTIDE – TREND

The two charts displayed in Figure 3 show the fit between observed water elevation at Martinez and astronomic tide (top) and planning tide (bottom). The planning tide model used does a good job at capturing changes in water elevation at Martinez during periods of high flow, as exemplified by the high flow period of February 1998. The SUBTIDE adjustment does away with much of the error left over from the harmonic analysis. For instance in the period June 1991 to September 2016 the RMSE from the harmonic analysis was 0.35 feet but the RMSE from the planning tide as a whole is 0.17 feet.

Figure 3. Comparison between Martinez Observed Tide, Astronomic Tide (top), and Planning Tide (bottom).



[2] https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9414290

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DSM2 Sediment Transport Model Development Update

En-Ching Hsu, Engineer WR, DWR
Jamie Anderson, Senior Engineer WR, DWR
Nicky Sandhu, Supervising Engineer WR, DWR

Background

The ability to model turbidity and sediment transport in the Delta is important in several ways for effective management of Delta resources. First, turbidity impacts Delta smelt's survival. It affects their feeding success in their larval life stage and their ability to avoid predation, and is a migratory cue. Sediment resuspension elevates turbidity and enhances Delta smelt habitat quality. Second, the ability to model turbidity and suspended sediment transport is essential for the development of a mercury model needed fulfill DWR's open-water compliance with the Delta Mercury Control Program (2011). For these reasons the California Department of Water Resources' Delta Modeling Section has been developing a new DSM2 transport module, called the General Transport Model (DSM2-GTM).

To date, DSM2-GTM accomplishments so far include integrating GTM into DSM2, and successfully simulating EC for the full Delta using a full cycle of DSM2-HYDRO and DSM2-GTM. Simulated historical EC from DSM2-GTM is consistent with the results from DSM2-QUAL. In addition, a new stand-alone suspended sediment module has been developed and calibrated and linked to turbidity, so DSM2 can now simulate the transport of suspended sediments. This independent sediment module can be adapted to other modeling contexts. The tasks remaining are: investigating factors for fine-tuning, conducting a sediment budget analysis and sensitivity analysis, and documentation. Details of progress, findings and remaining tasks are provided below.

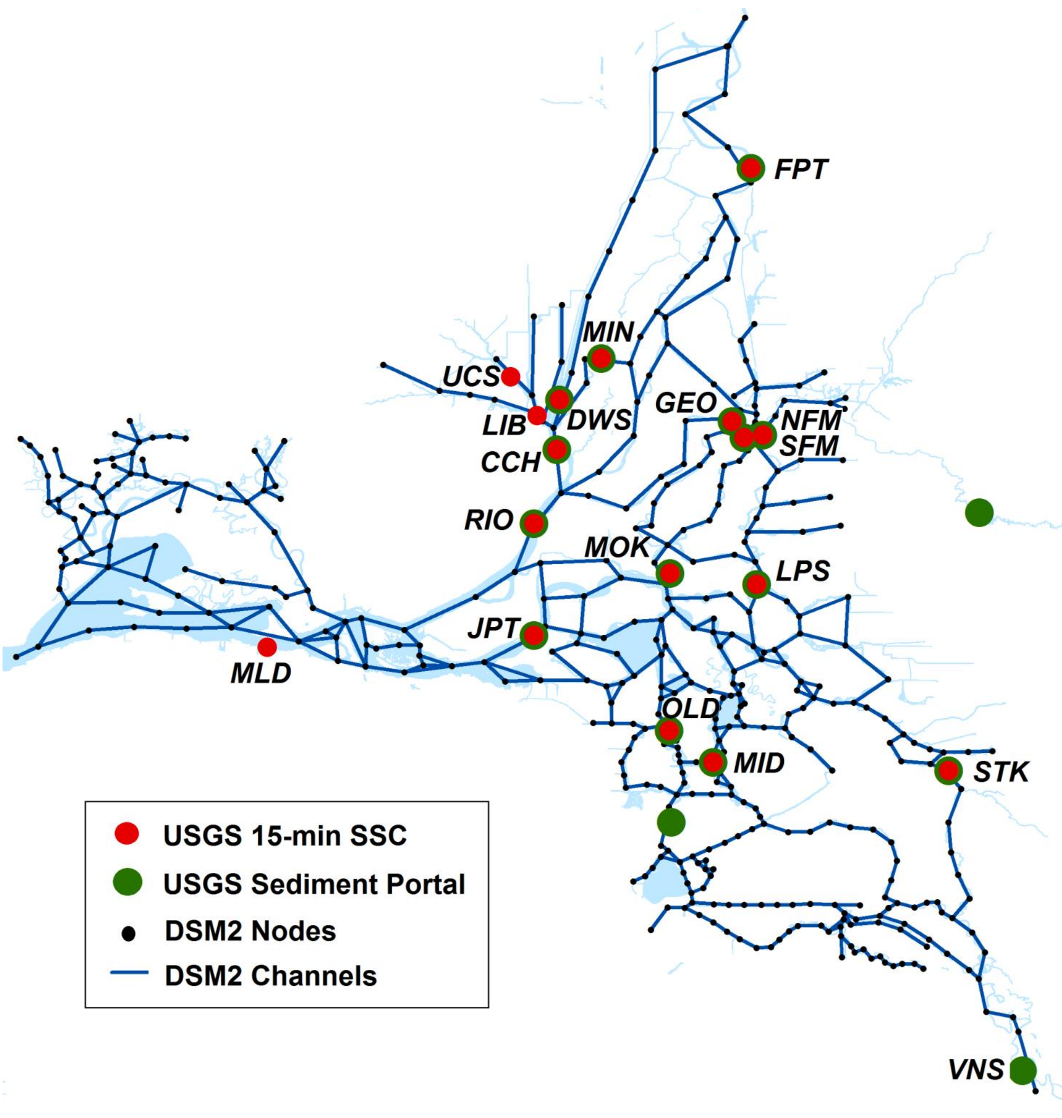
Completed Tasks

Data Collection. USGS has 17 continuous measuring stations for suspended sediment concentration (SSC). Reported data are derived from backscatter sensors measurements every 15 minutes, and are calibrated approximately monthly with bottle samples. Data are available from 2010 to current and were obtained from USGS in Sacramento (Morgan-King and

Wright, 2013). A map of the 15-minute data network and DSM2 grid is shown in Figure 1.

Model Development. Sediment entrainment and deposition are complex physical processes that are usually approximated by empirical equations. Erosion of cohesive sediment occurs whenever the flow velocity or the flow-induced shear stress over the bed exceeds a certain critical value. The erosion rate of cohesive sediment is calculated according to the formula of Partheniades (1962), while the deposition flux is expressed by a classical Krone (1962) formula. The net vertical sedimentation fluxes are treated as source and sink terms in DSM2-GTM's general transport equation. DSM2-GTM also provides the option of accounting for non-cohesive sediment by using Garcia and Parker's (1991) empirical equation.

Figure 1. USGS 15-minute and USGS Sediment Portal Sediment Data Network Overlapping DSM2 Grid



Initial Calibration. The calibration period is from October 2010 to September 2012, and currently the validation period is from October 2012 to February 2016. We are hoping to extend the validation period through water year 2017 with updated hydrology and boundaries in the final report. Throughout the modeling time-span, the computed results from DSM2-GTM reproduce observed peaks and capture trends when the concentration falls. The field measurements are cross-sectional averaged values, so a one-dimensional model to describe the system should be sufficient.

The sediment boundaries used are Freeport for the Sacramento River, Vernalis for the San Joaquin River, Cache Slough near Hastings Tract for the Yolo Bypass, and Mokelumne River at Walnut Grove Road. The hydrodynamics information,

Figure 2. Preliminary Subregions for the Calibration of Suspended Sediment Concentration

such as flow velocity, cross-sectional area, water depth, and channel roughness, are obtained from running DSM2-HYDRO under historical conditions. The adjustable parameters in the sediment module are sediment particle sizes for sand and fines (silt and clay), coefficients in the empirical equations, and the choice of equations. Initial testing simply applied these variables globally to observe overall response and sensitivity to adjustments, especially for regions in which sediment tended to be overestimated or underestimated. This practice helped us to establish the sub-regions (shown in Figure 2) for locally adjusting the parameters in order to match observed data.

Ongoing Tasks

We plan to complete the development, calibration, further analyses and documentation of the DSM2 suspended sediment model by the end of year of 2017. This model incorporates the advection and dispersion transport process with the reaction term and is implemented through empirical equations and the response of field data. Therefore, the development and calibration processes are coordinated to settle on the final assumptions. Tentative further analyses to be included in the final report are turbidity analysis, sensitivity analysis, and sediment budget analysis. Also, we are currently investigating isolated precipitation or heavy wind events that locally stirred up the sediment concentration. We are working on tests to evaluate the possibility of incorporating these factors into the sediment model.

With a longer record at our disposal, we were able to include more harmonic constituents and assess whether or not additional harmonic constituents could improve cross-validation prediction error.

Turbidity Analysis. We are investigating using simulated suspended sediment as a way to estimate water turbidity. First, a correlation between turbidity and suspended sediment data is found. The suspended sediment concentration can be calculated with the site-specific regression equation log10(SSC)=a*log10(Turbidity)+b. Using 15-minutes turbidity and sediment data from USGS's website, the best-fit parameters a and b are estimated to complete the equation. The results for Rio Vista, Middle River and Jersey Point are shown in Figure 3. These equations work well at those locations indicating that suspended sediment concentration and turbidity are highly correlated and the conversion is linear and straightforward.

Previous DSM2-based Delta turbidity studies by RMA (2008), Chilmakuri (2010) and Liu (2011) adopted the carbonaceous biochemical oxygen demand (BOD) function to simulate turbidity with the deoxygenation rate coefficient set to zero and the settling

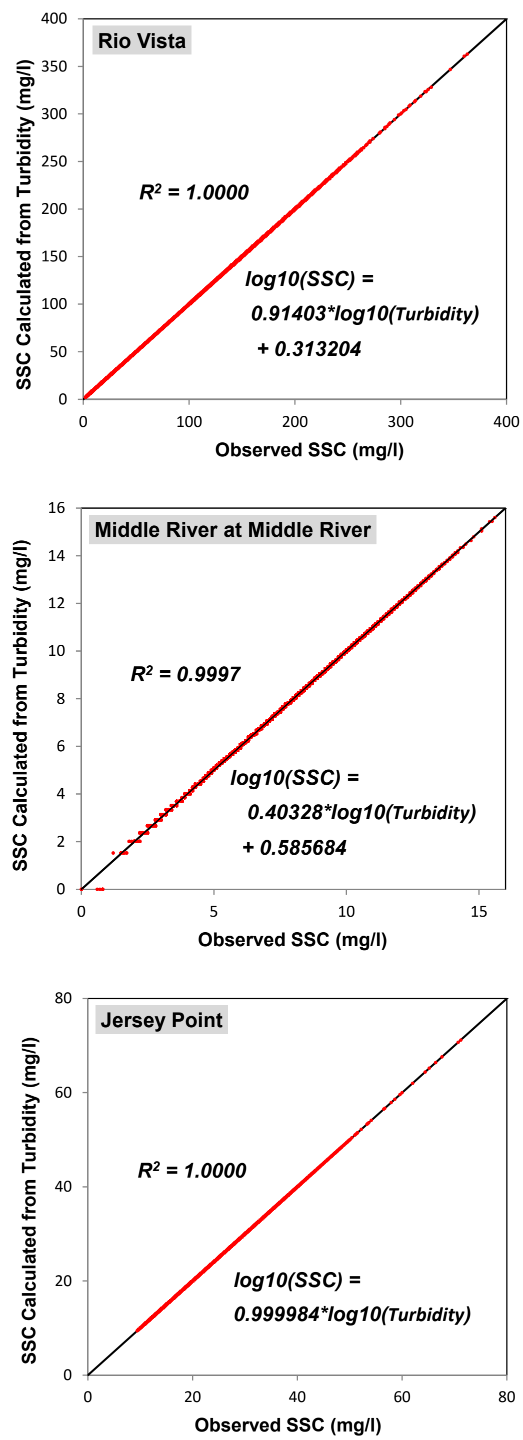


Figure 3. Regression Equations for Suspended Sediment Concentration and Turbidity

rate calibrated to simulate the loss due to settling. This approach was called the Delta Turbidity Model. RMA calibrated this model using the 2008 wet season from December 2007 to March 2008, while Liu (2011) calibrated based on the 2010 wet season from December 2009 to April 2010. These studies found that a model without both a resuspension mechanism and a consideration of flow velocity cannot capture system turbidity well under different hydrological conditions. GTM has both of these features.

DSM2-GTM simulates suspended sediment concentration, which can then be converted to turbidity by the derived regression equations. In order to compare DSM2-GTM to the previous turbidity model, it can mimick that model by including simple decay rates in calculating turbidity (Figure 4). The results at Rio Vista and Jersey Point (Figure 5) suggest that the sediment model better agrees with the observed data than does the turbidity model which intends to overestimate the peaks and underestimate during the dry season.

Sensitivity Analysis. We plan to perform hydrology-based sensitivity tests for the final report, increasing and decreasing by 10 percent: 1) Sacramento River inflow, 2) SWP pumping, and 3) DICU agricultural drainage flows.

Sediment Budget Analysis. A Delta sediment budget is usually analyzed by a pathway model which calculates sediment loads entering and exiting the north, central and south Delta regions. The

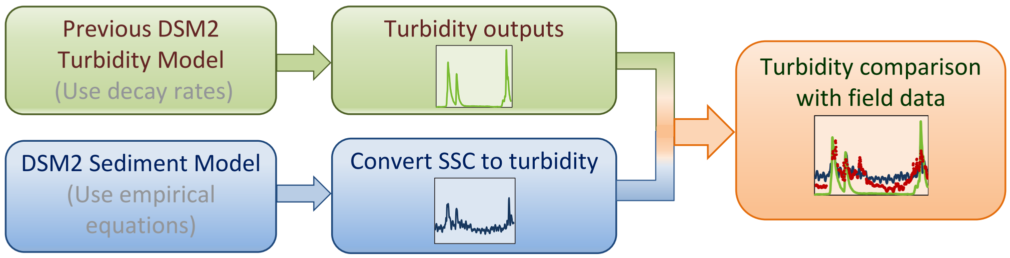


Figure 4. Schematic for Simulated Turbidity Comparison

primary pathways for the Delta are shown in Figure 6. This analysis will provide managers general information of the effects of sediment or turbidity on fish migration and salvage in terms of quantity and pathway of the sediment loads.

Precipitation and Wind Factors. At most locations in the Delta, the computed results from DSM2-GTM follow the trends of the observed data and are in reasonable agreement with the magnitude of the sediment concentration. At some locations, especially in central and south Delta, short term differences between simulated and observed values appear to be related to small tributary inflows or strong winds. An example from Little Potato Slough is shown in Figure 7. The highlighted period indicates that the sediment spikes seen in the field data cannot be related to boundary inputs and so are likely due to localized weather events.

These events make fine-tuning the model challenging. High wind speed does increase sediment concentration, but without direct association with hydrology for a one-dimensional model, rainfall seems a more intuitive option than wind to implement the model. In addition, wind speed data tends to be highly variable in magnitude and direction, while storm events are usually well defined. Ideally, Delta island runoff with heavier sediment loads can be introduced to the river system by

Figure 5. Turbidity Results Comparison among DSM2-STM, previous DSM2 Turbidity Model and Observed Data at Rio Vista and Jersey Point

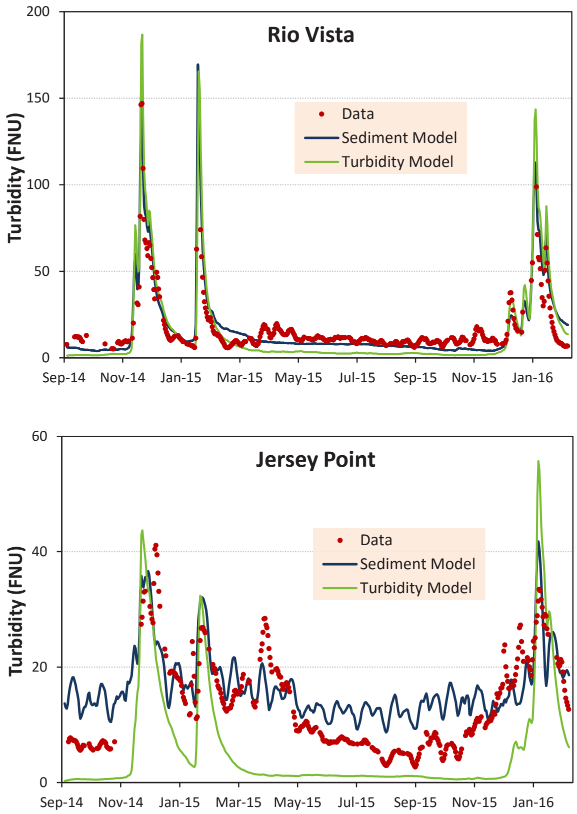
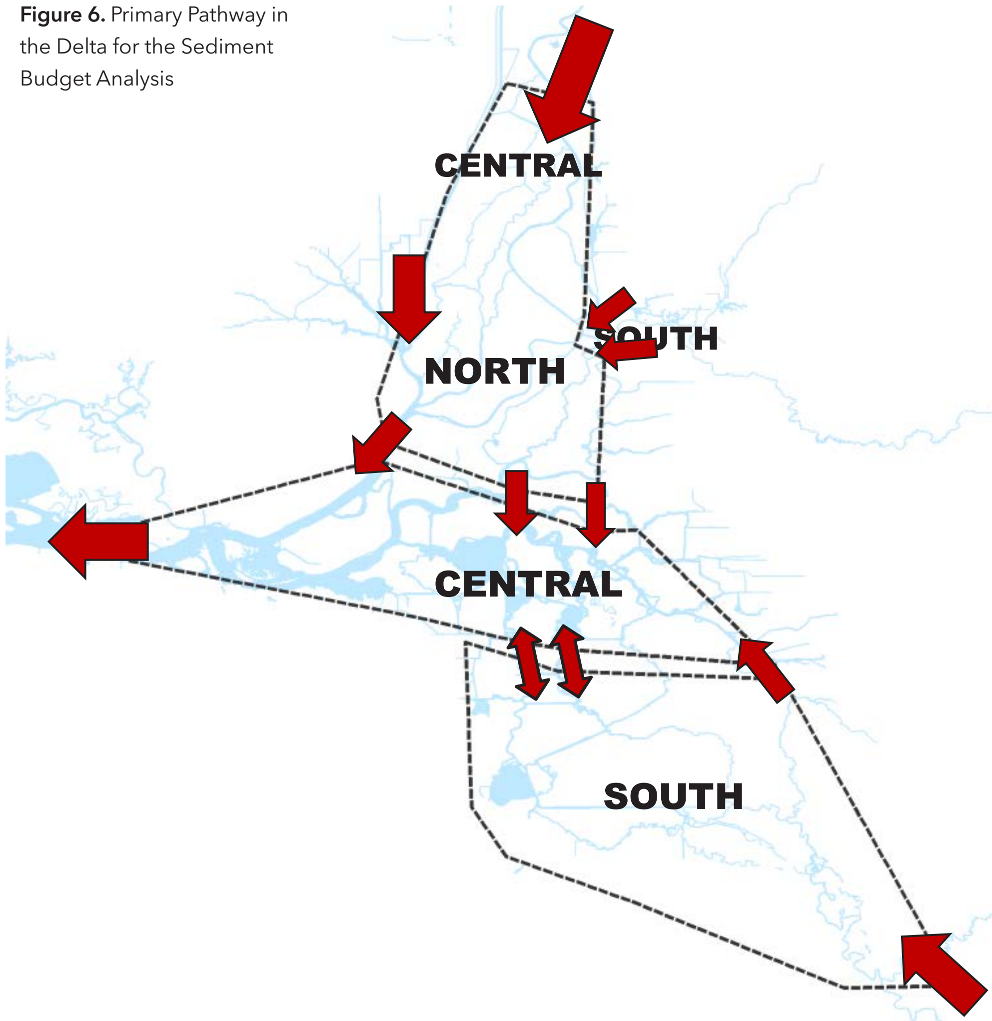


Figure 6. Primary Pathway in the Delta for the Sediment Budget Analysis



utilizing the Delta Island Consumptive Use (DICU) or Delta Evapotranspiration of Applied Water (DETAW) island drainage estimates. However, these models both have assumptions which could limit the usefulness of output drainage estimates: DICU run on a monthly time step and cannot capture individual storm events and DETAW assumes full soil saturation before runoff after precipitation. More work is required to investigate ways to incorporate those considerations into the model either by input data or possible model adjustment.

Sediment Bed and Mercury Cycling Modules. A parallel effort is ongoing for developing sediment bed and mercury modules. These two modules serve as extensions to DSM2-GTM. David Hutchinson from Reed Harris Environmental Ltd. is in charge of code development and our Modeling Support Branch is providing technical support for the integration effort.

Summary

The DSM2 Sediment Model, a time-efficient tool to estimate the suspended sediment concentrations in the Sacramento-San

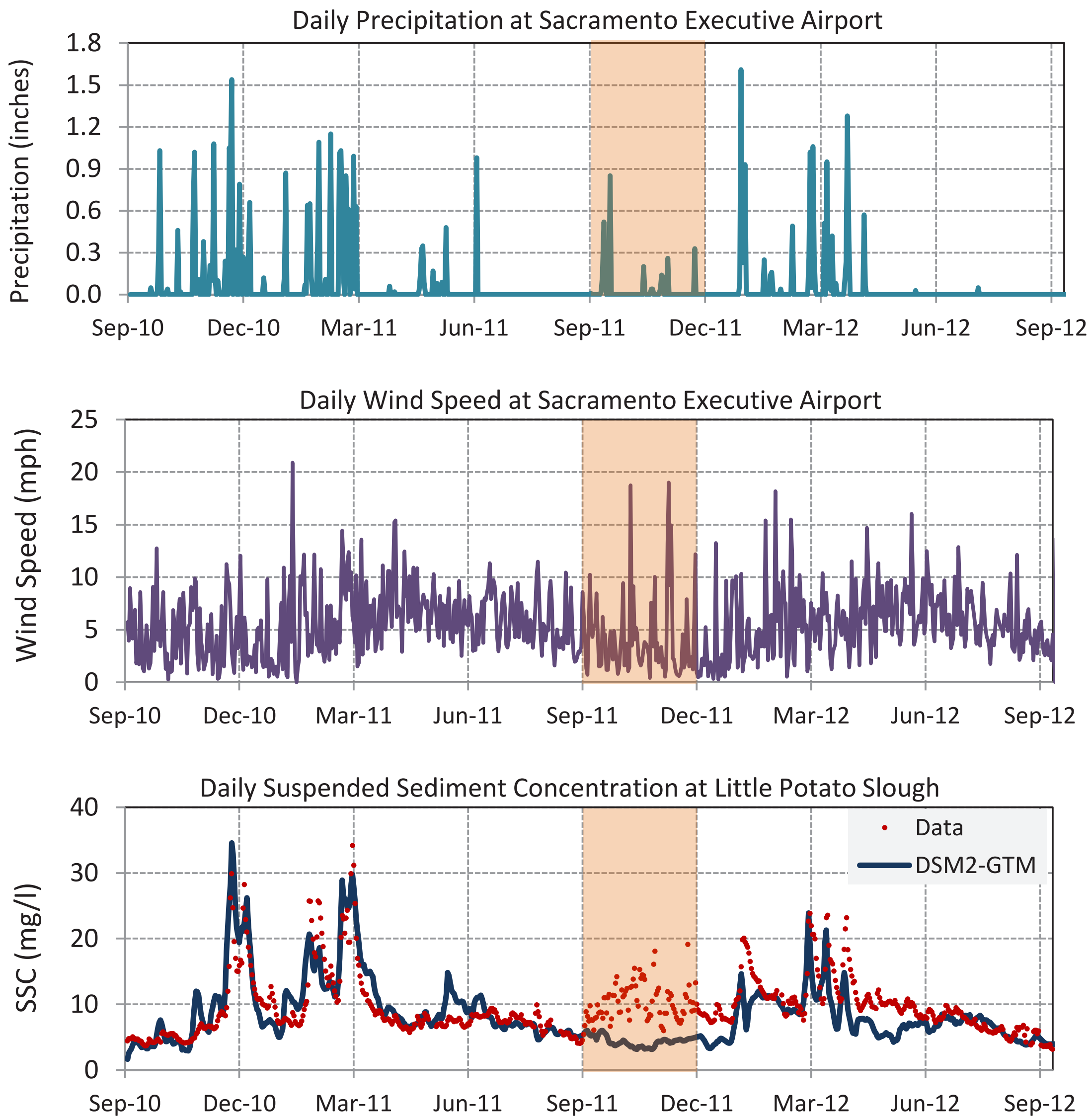


Figure 7. The highlighted area shows the effect of local storm and high wind events on the high SSC values.

Joaquin Delta, reasonably agrees with observed data. The model provides a systematic way to describe suspended sediment concentrations, while good quality continuous field data enhances the robustness of the model. Once the development, calibration and analyses are finalized, documented and released, further integrations with other applications and studies are expected.

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Modeling of Yolo Bypass using HEC-RAS 2D

Chakri Malakpet, Project Manager, CH2M
Steve Micko, Water Resources Engineer, CH2M

An Integrated Riverine and Floodplain Hydraulic Model of Sacramento River Basin

California Department of Water Resources (DWR) has collaborated with CH2M to develop integrated one-dimensional (1D) and two-dimensional (2D) hydraulic models for the Sacramento River Basin using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC RAS) version 5.0 modeling software. 2D models were developed for the bypass systems composed of Butte Basin and the Sutter and Yolo bypasses, for the Yuba River region and State Plan of Flood Control (SPFC) floodplains. Fully integrated 1D-2D models were constructed by combining these 2D models with a 1D system model representing the basin's riverine channel network.

The objective of creating integrated HEC RAS 1D-2D models of the Sacramento River system is to provide comprehensive tools to support flood management programs and projects in California. Specifically, the model was designed to accomplish the following key goals:

- Develop an integrated tool to generate high-resolution 2D simulation of floodplain hydraulics for urban areas and small communities in the Sacramento River system to delineate floodplains for flood risk management, floodplain management, and flood planning.
- Develop a high-resolution 2D simulation of the Yolo Bypass' interior downstream of Fremont Weir to model the impacts of different vegetation coverage in the bypass for ecosystem restoration analysis and to estimate annual habitat acres available for wildlife.

HEC RAS version 5.0 was used for this application, which can perform 2D (depth-averaged) hydrodynamic routing for 2D flow areas and represents a finite volume numerical model that computes depth and x and y velocity components for 2D cells by solving conservation of mass and momentum equations. It can use both structured and unstructured 2D computational mesh to represent a model's domain. The model is capable of capturing subgrid detail within each grid cell in its computations.

Yolo Bypass Model

The Sutter and Yolo Bypass model (SUTYOL) was one of the suite of models developed for this effort. This model includes 2D areas for Sutter Bypass from Colusa Weir to Fremont Weir, Yolo Bypass from Fremont Weir to Sacramento River confluence near Rio Vista, and portions of Sacramento River up to Collinsville. The model also includes Sacramento Bypass channel, and a portion of both the Feather and Sacramento rivers in the 2D area, and is connected to 1D modeling area, including a downstream reach of the Sacramento River and select surrounding storage areas. The spatial domain for the SUTYOL model is shown in Figure 1.

A system model specific to bypasses was constructed using the SUTYOL model and by integrating it with 2D areas representing Butte Basin and 1D modeling area representing riverine channels and floodplain storage areas for the entire Sacramento River SPFC domain. This model represents a comprehensive modeling tool that is capable of taking input hydrology below the dams (i.e. Folsom and Oroville Dam releases) and routing the flows through the flood control system including rivers, weirs and bypasses while providing high-resolution outputs for the Butte Basin, Sutter and Yolo Bypasses.

Model Input Data

The model was built using various datasets that defined physical and operational characteristics of the bypass elements. These datasets comprise of information related to topography, land cover, flood control structures, hydraulic structures and control features. The following sources of data were used in the model development:

- CVFED Program LiDAR survey (cell size of 3.125 by 3.125 feet) and bathymetric data
- DWR Northern Region Office Fremont Weir bathymetric survey data (Tule Canal above Knights Landing Ridge Cut (KLRC))
- CBEC's Tule Canal and KLRC bathymetric survey data (KLRC and Tule Canal below KLRC to Lisbon Weir)
- EDS Liberty Island bathymetry
- National Land Cover Database 2011 (NLCD 2011) 30-meter resolution land cover spatial data
- CVFED Program structural survey data (Weirs, Bridges, Culverts, Embankments etc)

Calibration and Validation

The model was calibrated to 1997 flood event using observed flow and stage hydrographs and high water marks collected post flood. For the 1997 calibration simulation, levee breaches that occurred during the 1997 flood event along Sutter Bypass, Feather River and Bear River were simulated in the model. Similarly, the validation of the model was performed using 2006 flood event hydrology. Overall, comparison of model simulated results against

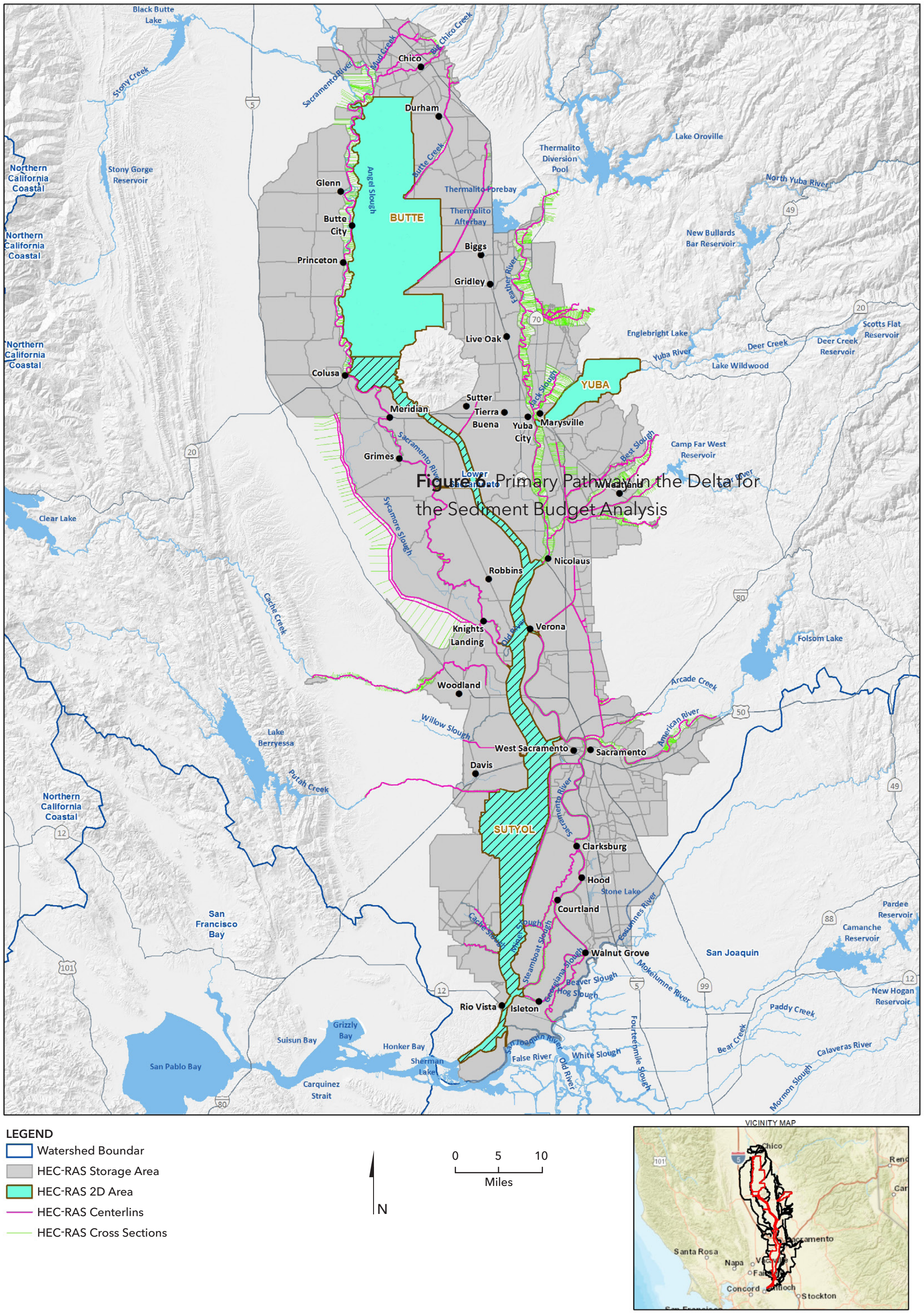
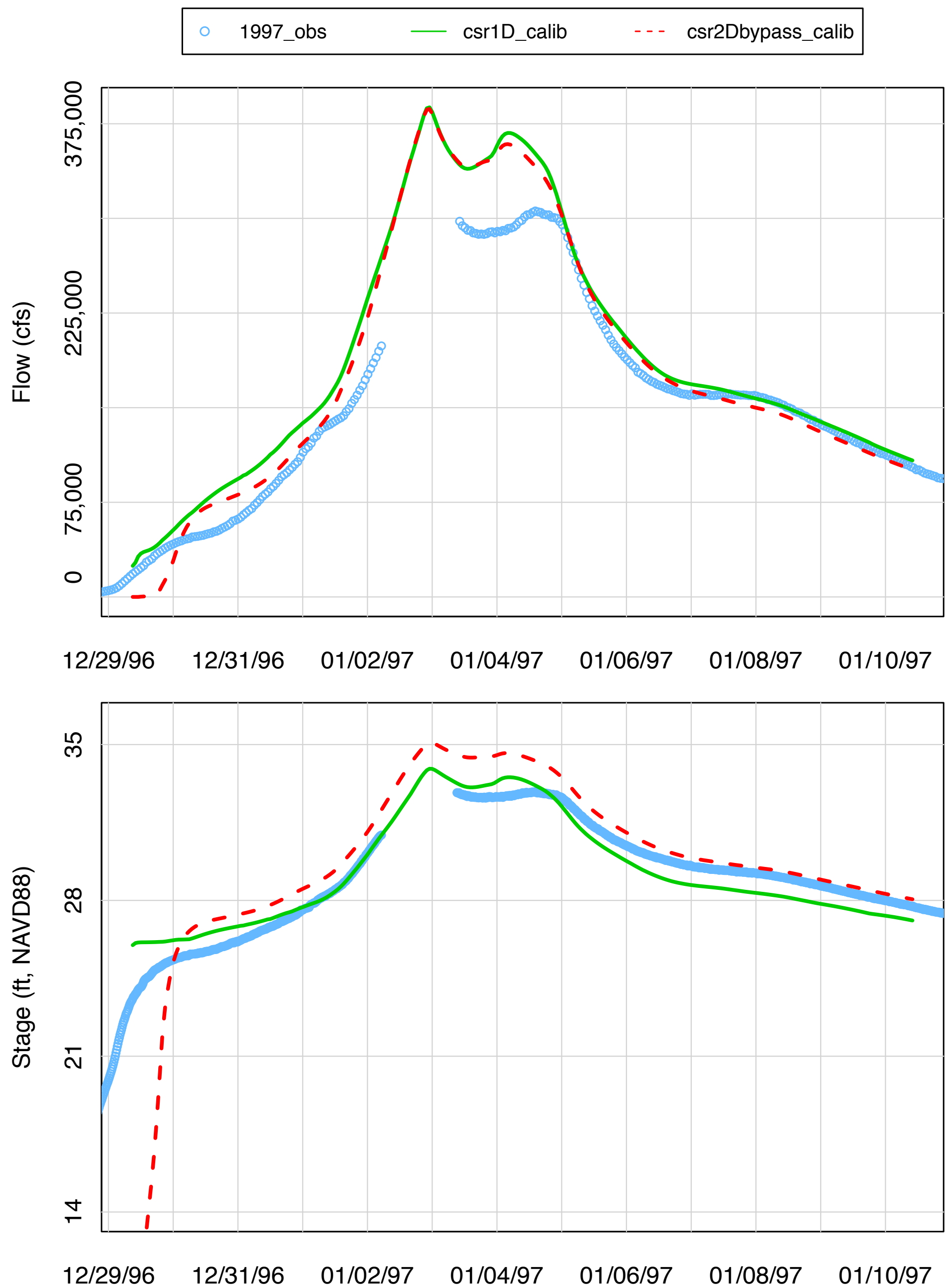


Figure 1. Integrated 1D-2D Bypass Model Domain

recorded observations of floods showed a good alignment of the simulated flow, stage, and floodplain inundation. Figures 2 through 5 demonstrate SUTYOL model calibration and validation performance with Sacramento River at Verona and Yolo Bypass near Woodland flow and stage hydrographs.

Figure 2. Yolo Bypass Woodland. 1997

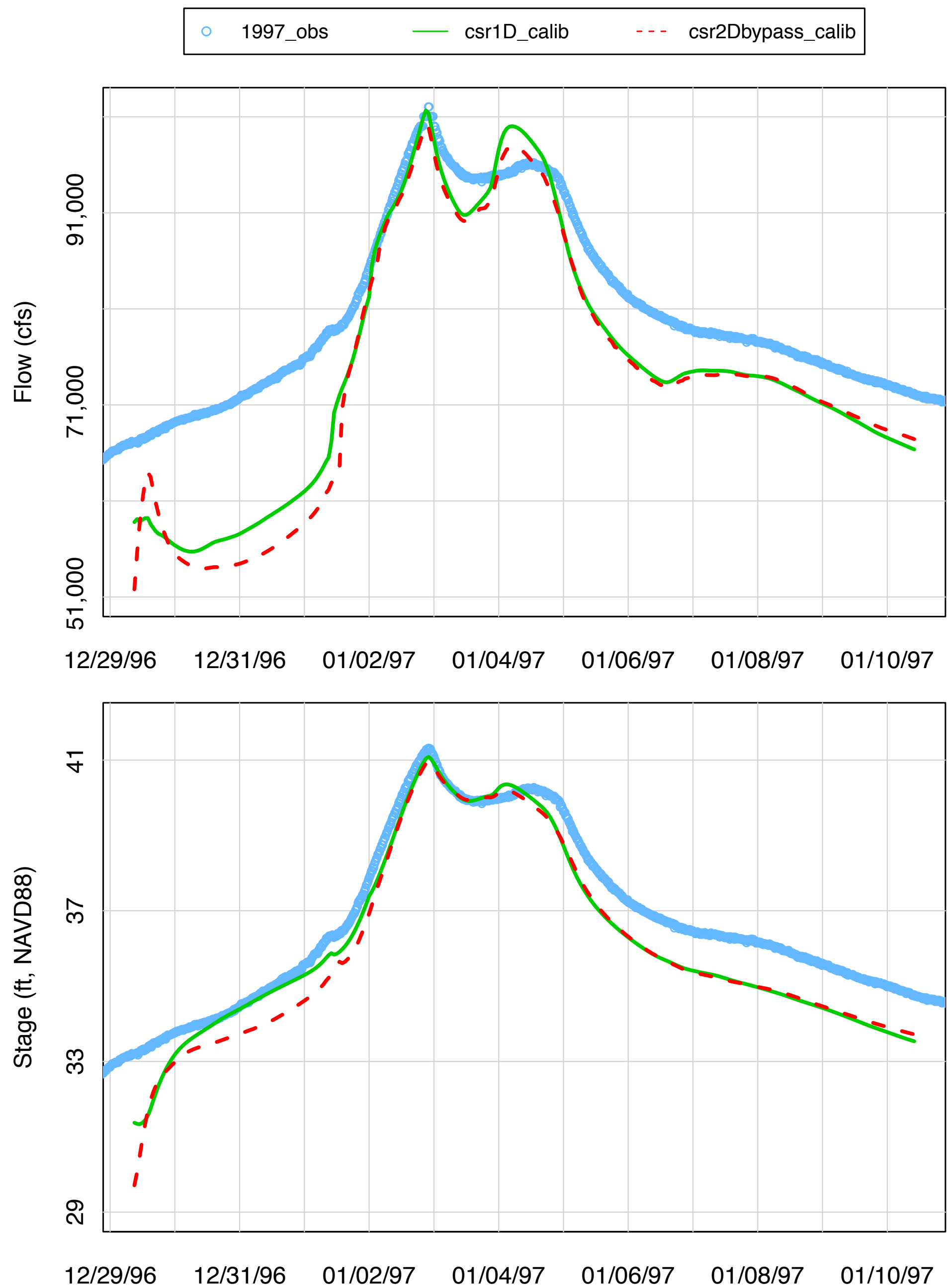


1997_obs – Observed data
csr1D_calib – Combined Sacramento River HEC-RAS 1D calibration model results
csr2Dbypass_calib – Combined Sacramento River SUTYOL Calibration model results

Model Applications

The SUTYOL model has an average spatial resolution of 200-feet cell size for the Sutter and Yolo bypasses, with finer resolution for the interior areas within bypasses along channels and embankments. This in combination with the subgrid detail captured from the terrain data results in

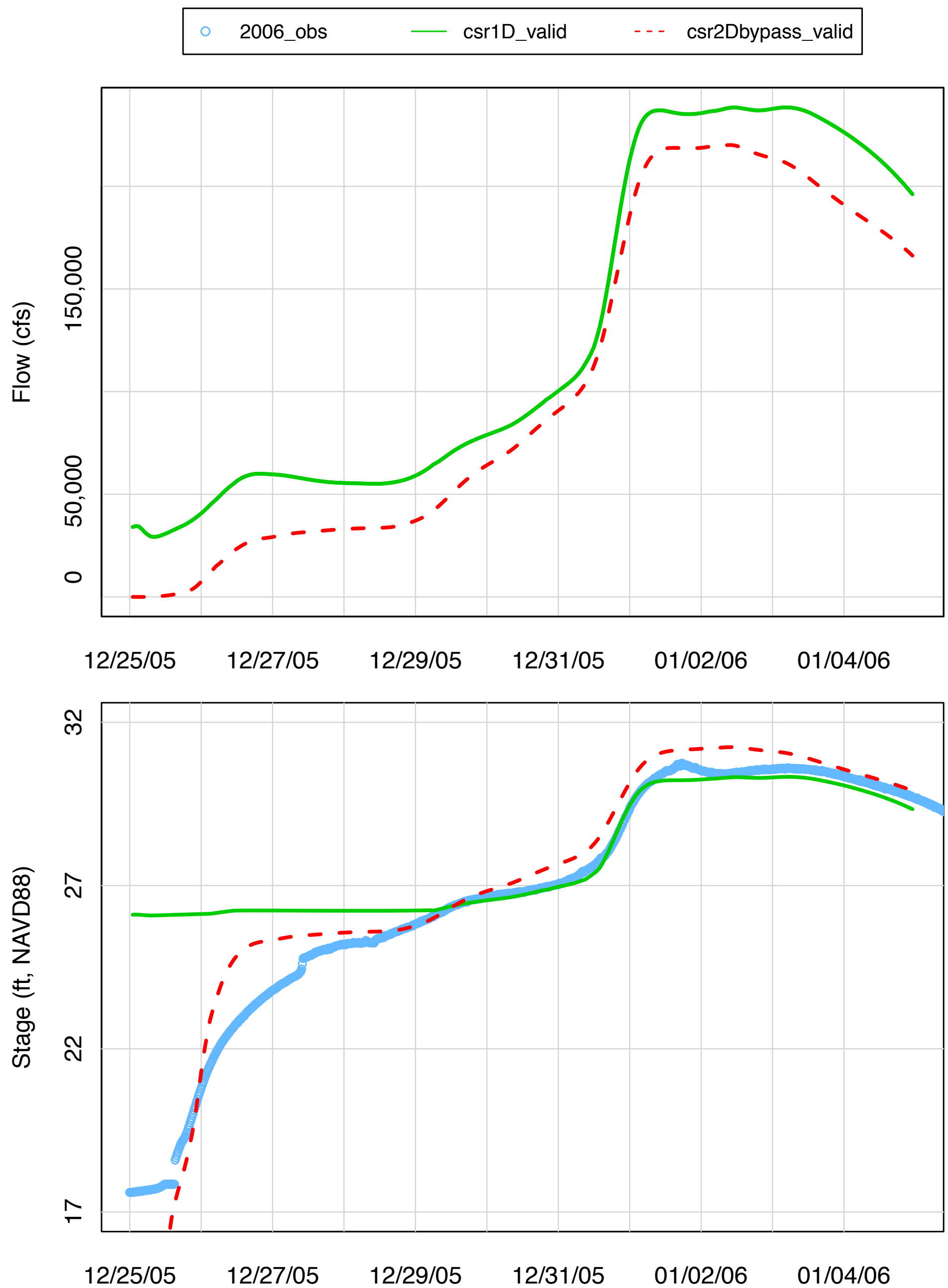
Figure 3. Sacramento River Verona



1997_obs – Observed data
csr1D_calib – Combined Sacramento River HEC-RAS 1D calibration model results
csr2Dbypass_calib – Combined Sacramento River SUTYOL Calibration model results

resolution spatial outputs. Examples of spatial outputs that can be generated using this model are: flood inundation depth, water surface elevation, velocity, shear stress, stream power, arrival time, duration, recession, percent time inundated etc. To demonstrate the utility of the model, Figures 6 and 7 show maximum

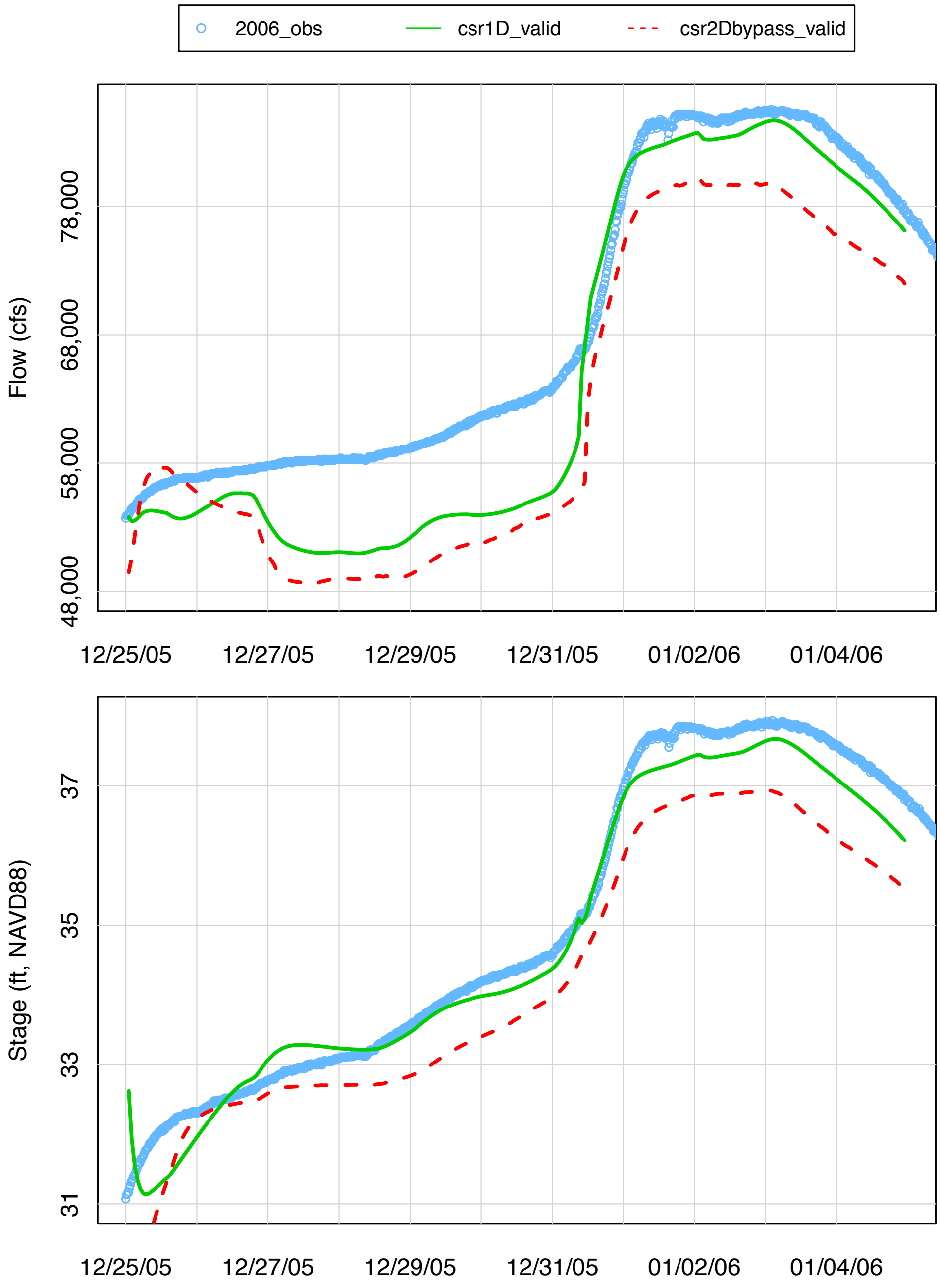
Figure 4. Yolo Bypass Woodland, 2006



2006_obs – Observed data
csr1D_valib – Combined Sacramento River HEC-RAS 1D calibration model results
csr2Dbypass_valib – Combined Sacramento River SUTYOL Calibration model results

inundation depth and maximum velocity for the 1997 flood event, respectively. Using the capability of this model to generate high resolution spatial outputs, the duration of flood water residing in the Yolo Bypass was computed for the 1997 flood event. The duration output indicates the time in hours that the inundation depth is

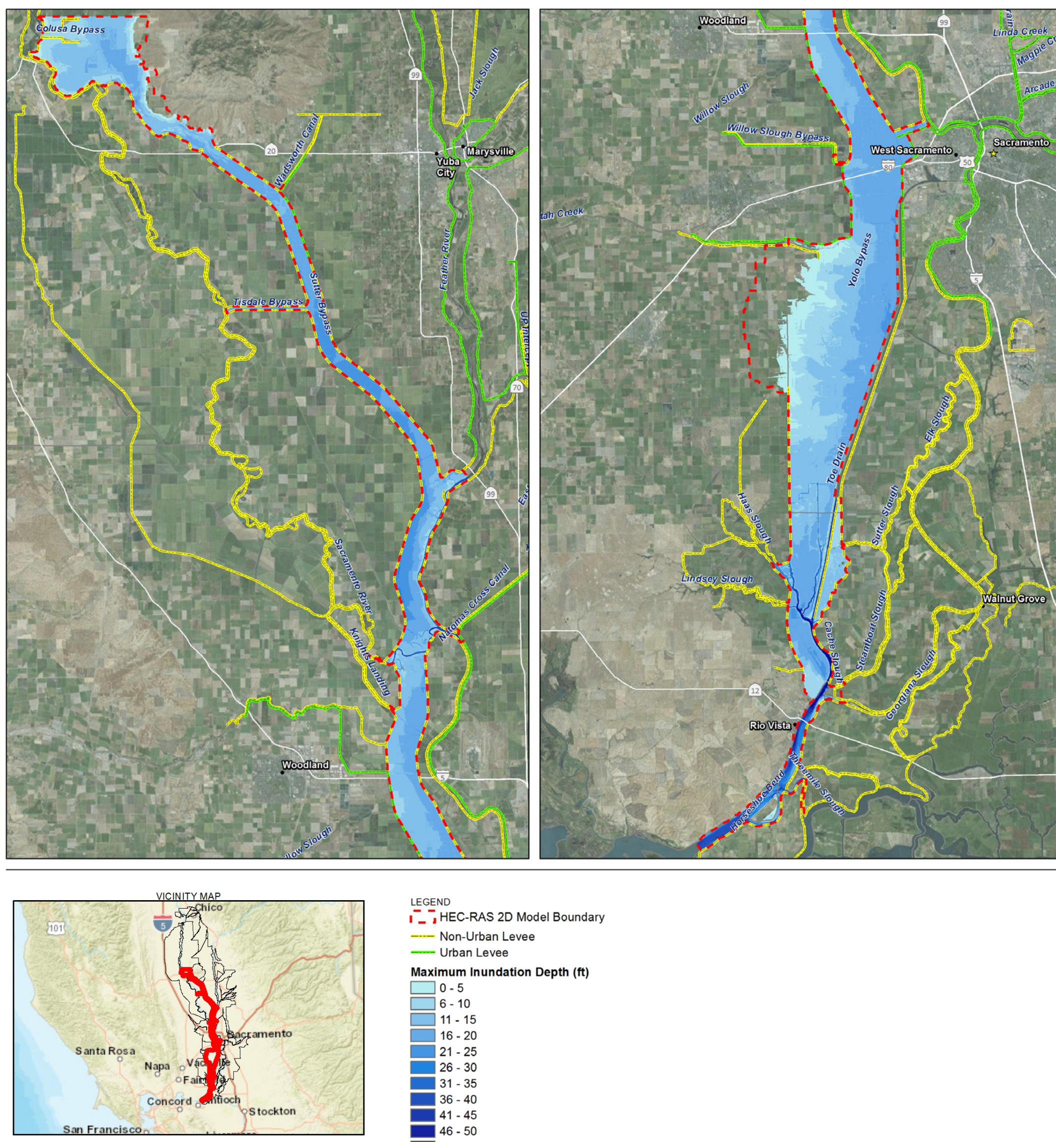
Figure 5. Sacramento River Verona, 2006



2006_obs – Observed data
csr1D_calib – Combined Sacramento River HEC-RAS 1D calibration model results
csr2Dbypass_calib – Combined Sacramento River SUTYOL Calibration model results

greater than the threshold depth. In other words, it is an indicator of residence time of water above certain depth. Duration output results are computed for each 2D cell and presented as a spatial map as shown in Figure 8. Spatial variability of duration can be assessed from the Figure 8, which identifies areas within

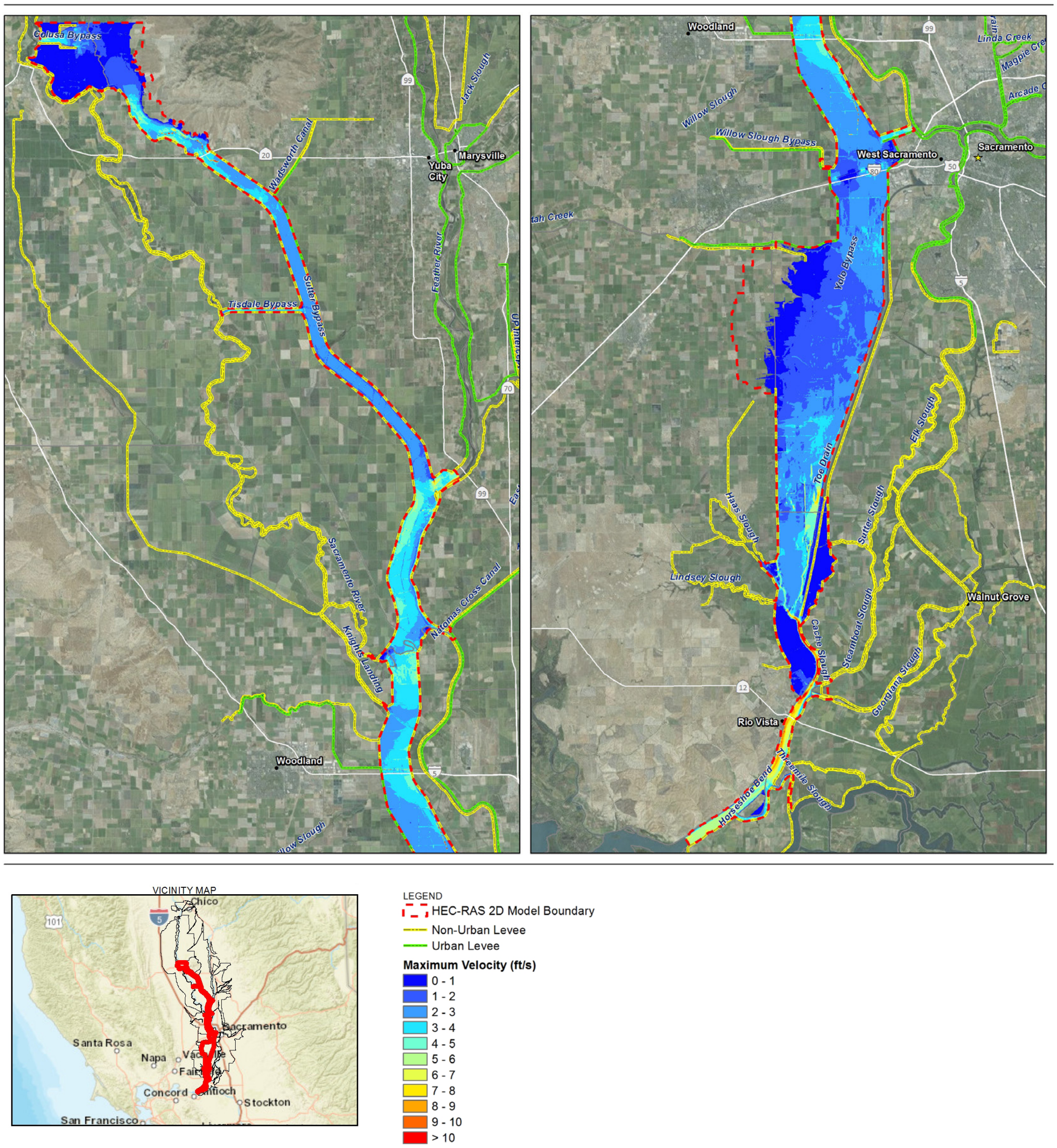
Figure 6. Maximum Inundation Depth Map – 1997 Calibration



that have longer duration and better connectivity of floodplains. Information presented in Figures 6, 7 and 8 can be helpful in assessing functional habitat for fish and other wildlife.

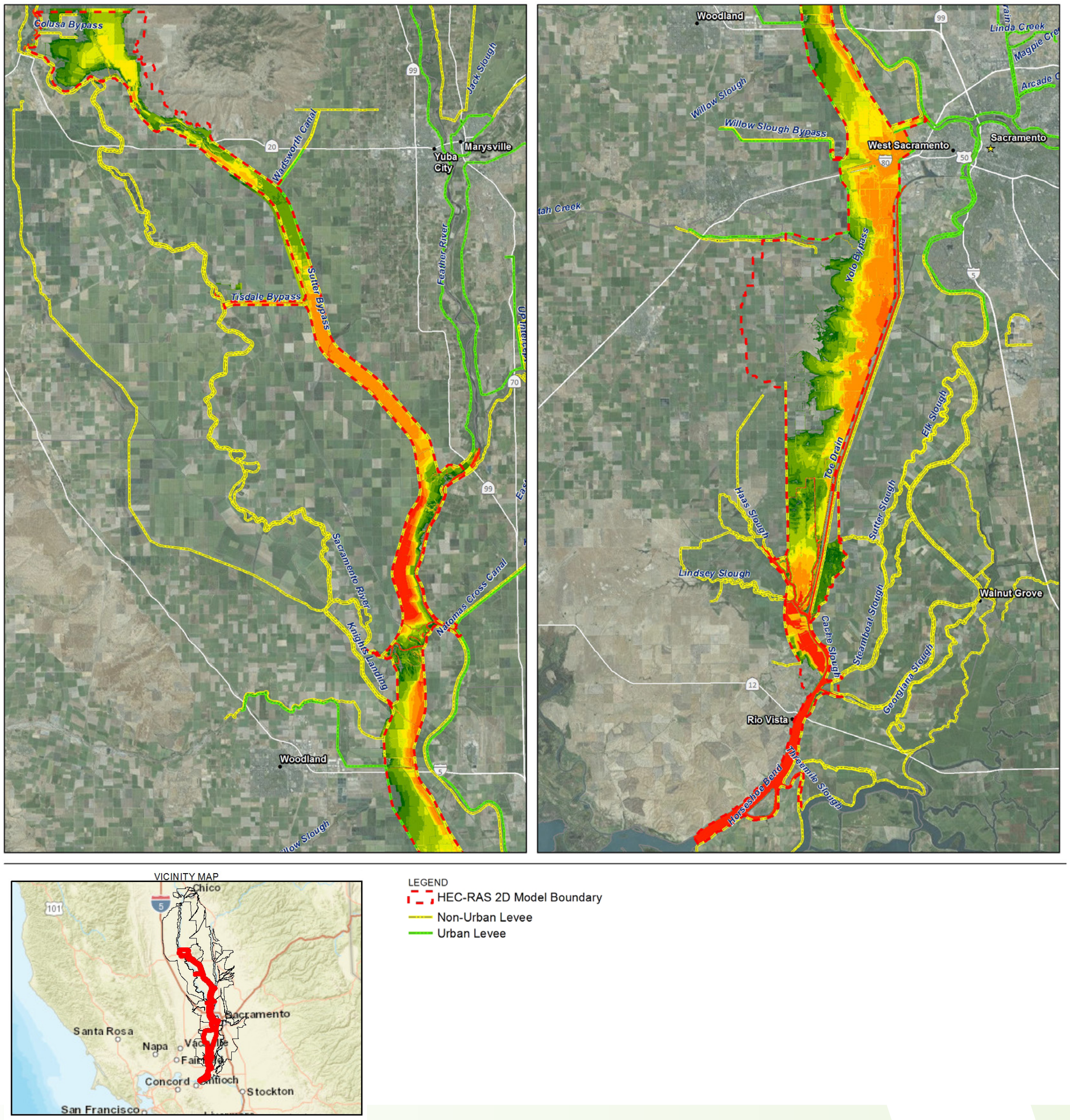
So far, this integrated model has been used to simulate large flood events in the

Figure 7. Maximum Velocity – 1997 Calibration



recent history. However, it can be used to simulate concepts to extend inundation through proposed weir modifications, proposed restoration concepts in the bypasses and at the same time evaluate the effects of the proposed concepts on the entire Sacramento River basin.

Figure 8. Duration Map – 1997 Calibration



Drivers of Change in Freshwater Flow to the San Francisco Bay-Delta

Paul H. Hutton, Principal Engineer, Tetra Tech Inc
John S. Rath, Environmental Scientist, Tetra Tech Inc
Sujoy B. Roy, Principal Engineer, Tetra Tech Inc.

Introduction

Freshwater flow through the Delta, usually reported in tidally averaged form as net Delta outflow, is essential for repelling salinity intrusion into the Delta and is critical to the ecosystem health of the estuary. Management of salinity in the Delta has been a long-standing concern (CDPW, 1931), and today is regulated to support both human uses and aquatic life (CSWRCB, 2006). More broadly, as part of efforts to restore the Delta ecosystem to a more natural state, there is great interest in understanding changes that have occurred in the freshwater flows and estuarine salinity as a consequence of changes in the watershed following European settlement in the mid-18th century. To partly address this need, we evaluated the nature of changes in Delta freshwater outflows, and the underlying drivers of those changes, over a subset of this period (water years 1922-2009) during which systematic measurements of flow and salinity are available. This article is a summary of a more detailed analysis presented elsewhere (Hutton et al., 2017a,b). The analysis recognizes that water year 1922 is not representative of pristine or natural conditions, and that numerous landscape changes had already occurred by this date . However, the watershed continued to undergo significant hydrologic alteration following this date, the most important being the construction of all major reservoirs in existence today and export facilities as well as the further conversion of undisturbed lands to irrigated agriculture.

[1] For recent work on natural or pre-development hydrologic and hydrodynamic conditions in the San Francisco Bay-Delta estuary and its watersheds, see Howes et al., 2015, Fox et al., 2015, CDWR, 2016 and Andrews et al. 2017.

Changes from baseline conditions were quantified and attributed to specific causes, such as reservoir operations or diversions.

Approach

As a first step in the analysis we examined trends in the observed Delta outflow time series over water years 1922-2009. In spite of increasing water use over the period examined, we found no statistically significant annual trend in the Delta outflows, a result likely due to large year-to-year climatic variability. Statistically significant trends were observed in seasonal outflows however, with significant decreasing trends observed in four months (February, April, May and November) and increasing trends observed in two months (July and August). Trend significance in early-to-mid autumn (September and October) was ambiguous due to uncertainty associated with in-Delta agricultural water use.

However, trend calculations on the observed data do not permit direct attribution of driving processes, particularly when multiple interacting processes are possible and where non-monotonic changes occur over an extended period of record. In addition to the trend analysis, therefore, we constructed alternative time series of daily Delta outflow corresponding to scenarios with different levels of development (land use and reservoirs) but forced by the same climatic record over a nine decade period. The idealized flow scenarios were constructed using two approaches: (1) a baseline scenario was developed using the results from an integrated hydrologic model (MWH, 2016) where land use was fixed at a 1920 level and (2) additional scenarios were developed by adjusting the historical Delta outflow for daily export operations and volumes released or stored by the ten major reservoirs in the watershed shown in Figure 1. Changes from baseline conditions were quantified and attributed to specific causes, such as reservoir operations or diversions. We also examined the effect of changes in Delta outflow on the salinity in the estuary using a newly developed artificial neural network-based salinity model that accounts for freshwater flow and coastal water level (Rath et al., 2017), allowing attribution of the effect of historical sea level rise in the region beyond changes in freshwater flow.

Five flow scenarios were developed in support of the change attribution analysis (Table 1). Scenarios 1A and 1B represent the historical daily outflow time series. While Scenario 1A represents the historical sea level record at Golden Gate, Scenario 1B assumes a de-trended sea level record (using linear regression) that is representative of 1920-level conditions. While coastal water level is subject to annual and decadal variation, a long-term rising trend of 1.9 mm/yr has been documented in the estuary (Ryan and Noble, 2007), corresponding to a change of 18.3 cm between 1920 and 2012. This de-trended sea level

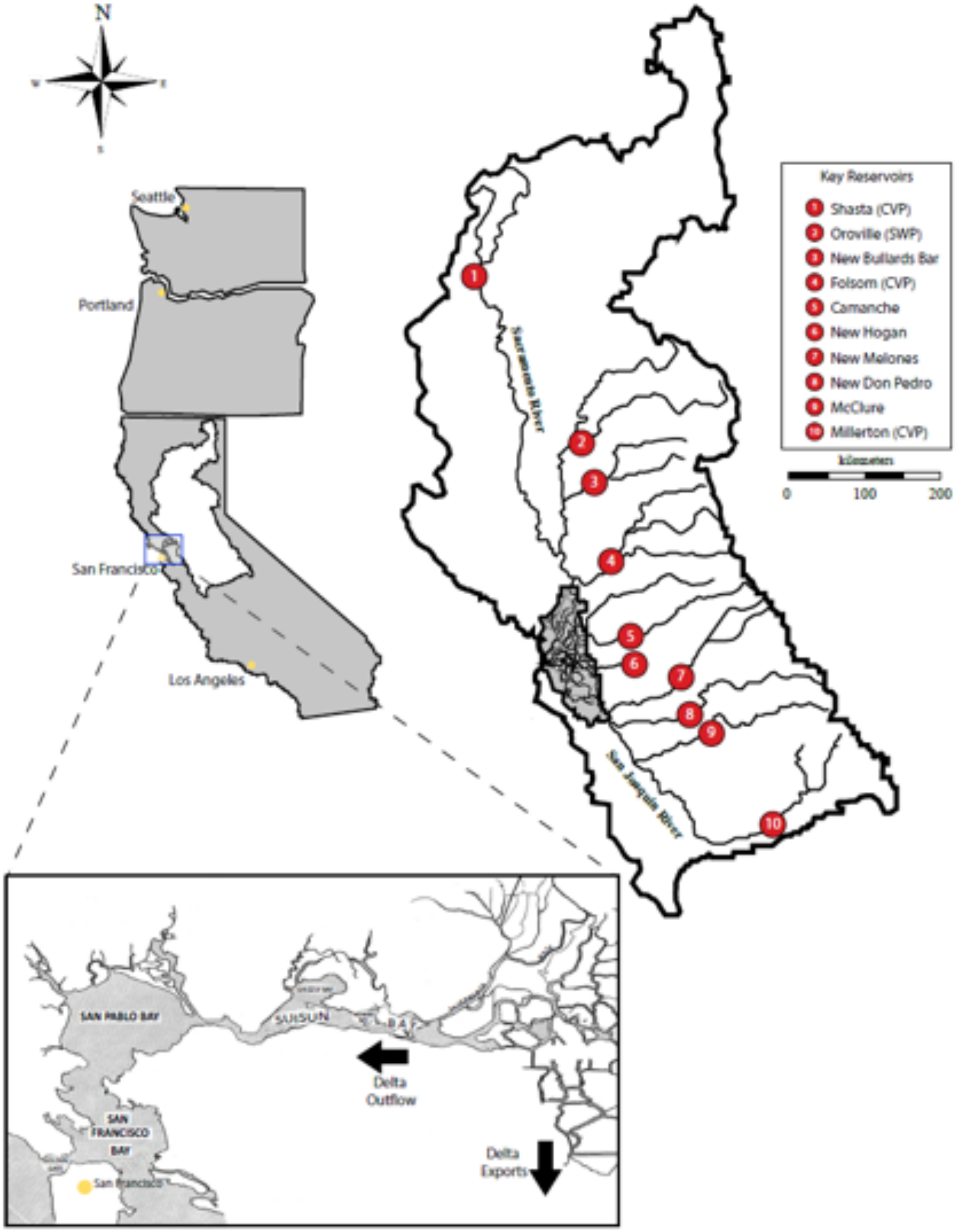


Figure 1. San Francisco Bay-Delta estuary and watershed showing the major rivers that flow through the California Central Valley, most of which are regulated through reservoirs. The ten major reservoirs in the Sacramento and San Joaquin River basins are identified, four of which are project reservoirs, identified as either CVP (Central Valley Project) or SWP (State Water Project). (Source: Hutton et al., 2017b).

record was also used for Scenarios 2, 3 and 4. In Scenario 2, the historical outflow record was adjusted (or "unimpaired") by removing the reservoir and export operations associated with the CVP and SWP. In Scenario 3, a modeling approach was used to generate a synthetic Delta outflow time series corresponding to a 1920 level of land and water use (MWH, 2016). Scenario 4 builds on Scenario 2 by removing operations of all ten major reservoirs shown in Figure 1.

The above flow scenarios, in conjunction with the principle of superposition (i.e. the individual drivers of flow change are additive and outflow and sea level together determine salinity), were used to ascribe outflow and salinity trends to specific drivers. Thus, by assuming 1920-level conditions (i.e. Scenario 3) as the baseline, the difference between Scenarios 1A and 3 corresponds to the total change. Similarly, the difference between Scenarios 1A and 1B corresponds to the change associated with sea level rise. The difference between Scenarios 1B and 2 isolates the effects of CVP-SWP project reservoir and export operations. The difference between Scenarios 2 and 4 is associated with effects of non-project reservoir storage, while the difference between Scenarios 4 and 3 is associated with effects of non-project diversions. All five change attribution categories (summarized in Table 2) are relevant for measuring salinity alterations, while four of the five categories are relevant for measuring flow alterations (sea level rise affects salinity only).

Results

Figure 2 shows Delta outflow and change times series over the analysis period spanning WYs 1922-2009. The top panels show historical (i.e. Scenario 1A) Delta outflow for months that were shown to have statistically significant trends, with adjacent months combined, and as an annual average. The bottom panels show outflow change for each of the attribution categories (excepting sea level) identified in Table 2. The principle of superposition dictates that the change associated with the three project and non-project categories sum to the total change. As discussed previously, change is measured relative to a 1920-level baseline (i.e. Scenario 3). February and November outflow changes are primarily attributed to project effects, although non-project effects (the combination of non-project storage and diversions) account for some of the February Delta outflow change after about 1980. Total February and November outflow changes over the period of analysis are less than 2 MAF and 0.5 MAF, respectively. In the months of April-May, outflow change is negative for all categories after about 1950. The sum of non-project storage and diversion effects is visually similar but somewhat smaller than the project effect. Total April-May outflow change over the period of analysis is less than 3 MAF, with the negative trend flattening by about 1980. Outflow change in the months of July-August is distinctly different from the other periods analyzed. One notable difference is that the trajectory of total outflow change is positive over the period of record. Another notable difference is

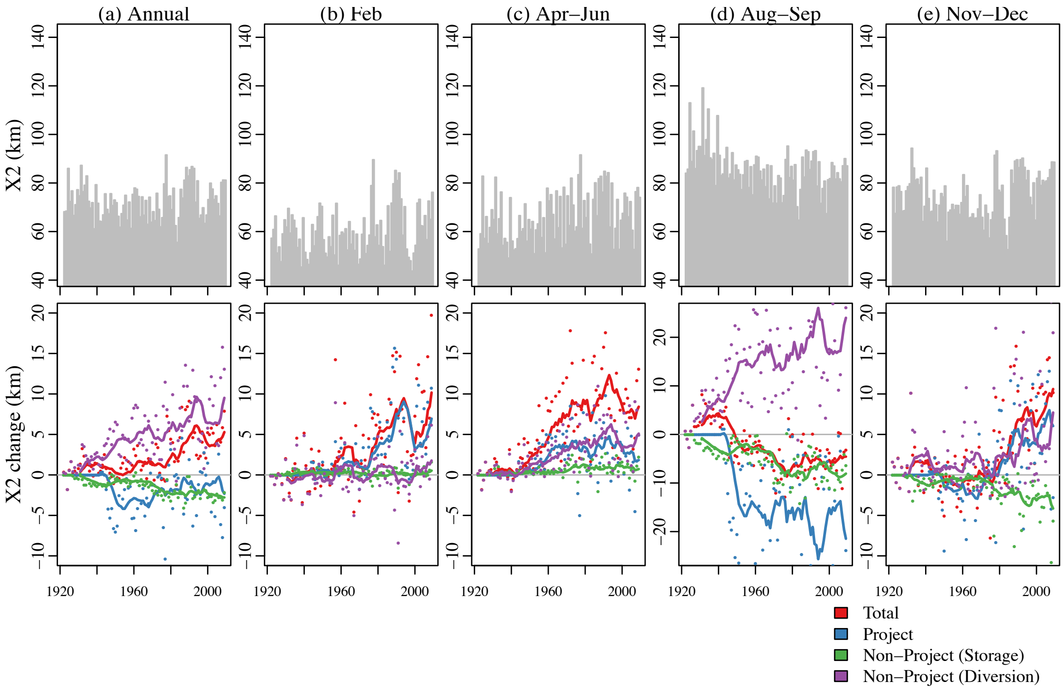


Figure 2. Historical Delta outflow and change time series over WYs 1922-2009 for (a) February, (b) April-May, (c) July-August, (d) November, and (e) annual flow. The top panel represents historical flows (Scenario 1A). The bottom panel represents change attribution categories identified in Table 2, as shown in individual data (points) and 10-year moving averages (lines). The time periods are limited to months with statistically significant trends in historical Delta outflow (Source: Hutton et al., 2017b).

that the total outflow change switches from negative to positive in the 1950s. Positive outflow change is attributed primarily to project effects and to a lesser degree non-project storage. These effects more than fully attenuate impacts associated with non-project diversions. On an annual basis, the outflow change is negative for all categories with the project and non-project diversions being the primary and secondary drivers of change, respectively. Both categories show a similar trajectory through about 1980; thereafter the project change continues to trend negative whereas the non-project diversions change flattens. Total annual outflow change over the period of analysis is approximately 8 MAF.

Figure 3 shows Delta salinity (expressed as X2 position) and change times series over the analysis period spanning WYs 1922-2009. The top panels show historical (i.e. Scenario 1A) X2 position for months that were shown to have statistically significant trends (with adjacent months combined) and as an annual average. In this presentation, X2 was computed on a daily basis, and averaged over different periods, either annually, or over one or more months. The bottom panels show salinity change for each of the attribution categories (excepting sea level) identified in Table 2. Sea level change was observed to have a small impact on salinity relative to the other drivers;

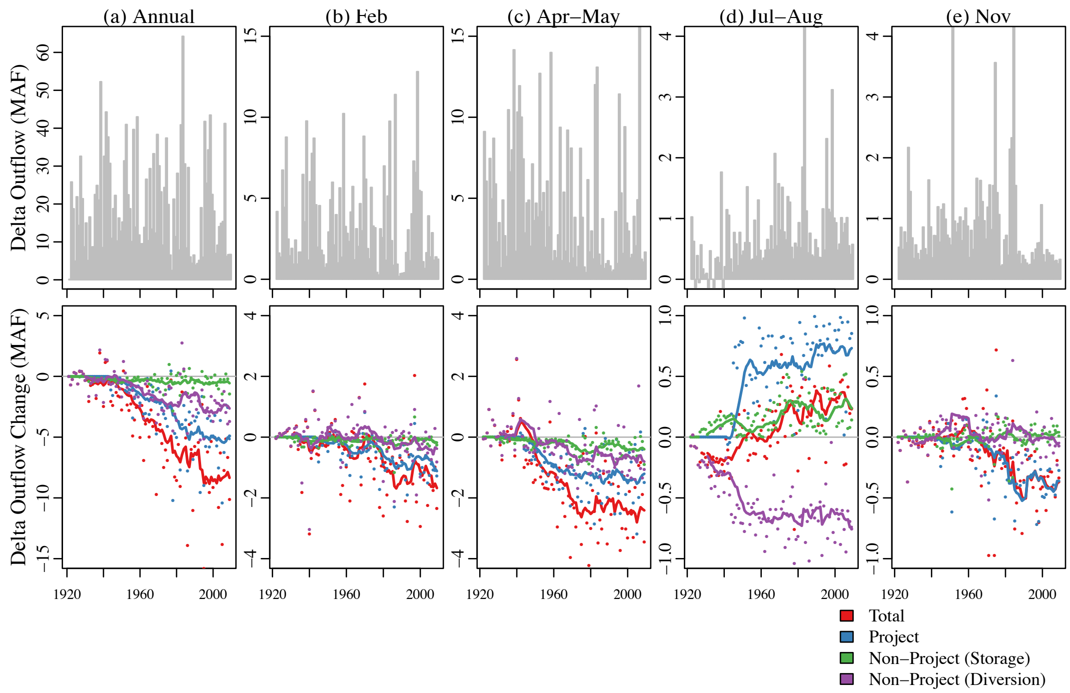


Figure 3. Historical salinity, represented as X2 position, and change time series over WYs 1922-2009 for (a) February, (b) April-June, (c) August-September, (d) November-December, and (e) annual average. The top panel represents historical salinity (Scenario 1A). The bottom panel represents the change attribution categories identified in Table 2, as shown in individual data (points) and 10-year moving averages (lines). The time periods are limited to months with significant X2 trends over the simulation period spanning WYs 1922-2009. Because of the lagged salinity response to flow changes, months with significant salinity change often extend beyond the periods with significant flow change (depicted in Figure 4). (Source: Hutton et al., 2017b).

therefore it was not shown in Figure 3 for visual clarity. X2 position is strongly related to antecedent Delta outflow conditions (Hutton et al., 2015); thus, salinity response tends to lag the flow signal. Because of this time lag, months with significant change often extend beyond the periods with significant changes in flow as shown in Figure 2. This lag effect is illustrated by the statistically significant outflow changes in July-August manifesting statistically significant salinity changes in August-September, and the November outflow changes manifesting in November-December salinity changes.

Positive X2 change in February (Figure 3a) appears to escalate after the 1960s. This change is attributed largely to project effects and results in an upstream X2 movement of 5-10 km (compared with the 1920 baseline) by the end of the simulation period. In comparison, positive X2 change in April-June (Figure 3b) begins early in the simulation period, with an approximately 10 km increase by the end of the simulation period. These changes are roughly attributed equally to project and non-project diversion effects. August–September X2 change has been significant since the beginning of the simulation period (Figure 3c). Individual driver effects are large relative to total X2 change (an approximate 5 km decrease from the baseline). Furthermore, individual driver effects are strongly divergent. An increase in X2 position of approximately 20 km is attributed to non-project diversions, and an opposite and roughly equal decrease in X2 position is attributed to project effects. The net change in August-September X2 position is thus associated with the remaining non-project storage effect. Positive X2 change in November-December appears to escalate by the 1980s and reaches a level approximately 10 km greater than the baseline toward the end of the simulation period (Figure 3d). This change is attributed roughly equally to project and non-project diversion effects; non-project storage is associated with a small decrease (about 5 km) in November-December X2 position by the end of the simulation period.

Table 1. Summary description of hydrology and sea level assumptions associated with the five idealized flow scenarios defined for the change attribution analysis. (Source: Hutton et al., 2017b)

Scenario ID	Scenario Description	
	Hyrology	**Sea Level**
1A	Historical	Historical
1B	Same as Scenario 1A	Historical de-trended to represent 1920-level conditions
2	Scenario 1A + unimpairment of CVP-SWP storage and export operations	Same as Scenario 1B
3	1920-level land use and water management conditions[1]	Same as Scenario 1B
4	Scenario 2 + unimpairment of key non-project storage operations	Same as Scenario 1B

[1] Hydrology is based on an integrated hydrologic model of the Central Valley; simulated data were bias corrected using observed data

Table 2. The idealized flow scenarios identified in Table 1, in conjunction with the principle of superposition, are used to ascribe outflow and salinity trends to different anthropogenic and natural causes (identified below as flow and salinity change attribution categories). By retaining a fixed climatic record, the analysis approach removes precipitation as a factor underlying outflow and salinity trends. (Source: Hutton et al., 2017b).

Change Attriution Category	Calculation Approach	Relevance
Total	Scenario 1A – Scenario 3	Outflow/salinity
Sea Level	Scenario 1A – Scenario 1B	Salinity
CVP–SWP Projects	Scenario 1B – Scenario 2	Outflow/salinity
Non-Project Storage	Scenario 2 – Scenario 4	Outflow/salinity
Non-Project Diversion	Scenario 4 – Scenario 3	Outflow/salinity

Our analysis suggests that project operations are a primary driver of Delta outflow change in all months when trends are statistically significant.

The total change in X2 position is positive on an annual basis (Figure 3e), which is consistent with the negative change in total outflow shown in Figure 2 (i.e. X2 position increases as outflow decreases). Project and non-project storage effects both decrease X2 position (i.e. push salinity downstream) on an annual basis, whereas the non-project diversion effect increases X2 position (i.e. push salinity upstream). While this result may initially seem counterintuitive given that project effects decrease annual outflow (Figure 2e), it is important to highlight the substantial role of the projects during low flow periods. Project outflow contributions during low flow periods (Figure 3c) result in large reductions in X2 position in the subsequent months, as X2 is highly sensitive to Delta outflow changes under low flow conditions (Rath et al., 2017). For example, although a relatively small change in August Delta outflow will have a minimal effect on aggregate annual outflow, the small flow change can have a substantial effect on August-September X2 position, such that the annual X2 position (computed as an arithmetic average over all days in a year) shows a meaningful change.

Summary

By utilizing a model-based approach and assuming fixed climatology, a clearer picture of annual outflow trends and drivers of change emerges at a level of detail not possible through the observational data record. Our analysis of annual outflow suggests that (1) declines through the mid-to-late 1970s are attributed equally to project operations and non-project diversions, (2) further declines through the 1980s are attributed to project operations, and (3) flow appears to stabilize by the 1990s. These change points are consistent with the peaking of irrigated acreage in the watershed by the mid-1970s (Hutton et al., 2017a), increasing Delta exports following expansion of the CVP and construction of the SWP in the late 1960s, and increasingly restrictive Delta outflow standards.

Similarly, this analysis provides a quantitative picture of monthly outflow trends and drivers of change. Our analysis suggests that project operations are a primary driver of Delta outflow change in all months when trends are statistically significant. For example, in July and August, flow contributions from project operations counter the effect of increasing non-project diversions. Absent these project flows, non-project diversion effects would have been much greater than observed after the 1940s. Indeed, low summer and fall Delta outflow events (and commensurate salinity intrusion) were common just prior to the 1920s through the mid-1940s (CDPW, 1931). Following this period, the largest reservoir in the watershed (Lake Shasta) became operational. Lake Shasta, in tandem with other project reservoirs, now provides a flow contribution greater than the flow reduction due to upstream non-project diversions, resulting in a net increase in summer outflow relative to the 1920- level baseline. Non-project reservoirs also provide additional summer outflow, but are smaller contributors due to their lower storage capacity and their differing purpose. Non-project reservoirs are generally operated to meet water needs within the watershed, whereas project reservoirs are operated in part to meet Delta outflow standards.

This work reveals that the earliest and largest salinity (X2) changes occurred in August and September, an effect of antecedent flow changes in July and August. Non-project diversions result in increasing X2 position during these months from the beginning of the record to the mid-to-late 1970s. Project operations were associated with substantial X2 declines during these months after completion of Lake Shasta (mid 1940s) through the 1950s. Project operations and non-project diversions are equally important contributors to increasing salinity in the spring (April-June) between the 1940s and the 1980s. Non-project storage is a secondary contributor to increasing salinity during this period. Project effects reflect increasing reservoir storage capacity, whereas non-project diversion effects reflect increasing irrigation demand. The cessation of spring X2 increase following the 1980s is attributed to reduction in Delta exports in response to more stringent outflow standards and stabilized irrigation demand. Increase in February X2 is primarily attributed to project operations, reflecting a month when irrigation diversions are minimal. Notable change relative to the baseline began in the 1970s and likely reflects a shift in Delta exports from spring to winter months. Increase in November-December X2, notable from about 1980 to the end of the simulation period, is equally attributed to project operations and non-project diversions. The attribution to project operations may reflect a shift in Delta exports from spring months; the association between non-project diversions and November December X2 increases is not well understood.

Results from this attribution analysis show the highly dynamic nature of the estuary over a nine decade period spanning WYs 1922-2009, with different drivers being dominant in different periods and seasons. In principle, this general framework is equally applicable to pre-1920 level conditions, where drivers unique to this period dominated hydrologic changes. Evaluation of drivers of change in freshwater flow and salinity over a longer time horizon is envisioned in a future phase of this work.

Acknowledgements

Funding for this work was provided by the (California) State Water Contractors, the San Luis & Delta-Mendota Water Authority, and the Metropolitan Water District of Southern California; supplemental support was provided for SBR and JSR through a grant from the National Institute of Food and Agriculture of the U.S. Department of Agriculture. The authors acknowledge Dr. Andy Draper's contribution in the area of modeling related to the historical water resources development of the Central Valley.

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Bay-Delta SCHISM Update

Eli Ateljevich, Senior Engineer WR, DWR

Hi everyone. Welcome to the first update on the latest happenings with Bay-Delta SCHISM, our public 3D model, which we hoping to incorporate more in the user group and newsletter.

Projects

Several of our Bay-Delta SCHISM applications at the moment center on the Delta Smelt Resiliency Strategy, a California Resources Agency plan to stem the urgent decline of smelt populations in recent years. We are involved in two of the smelt proposals. One project that is being investigated by California Department of Fish and Wildlife involves restoring the western part of Franks Tract as a tidal marsh. The possible benefits of this project come from preventing entrainment through False River tidal exchange with the main conveyance corridor, food production, reduction of predator habitat, and possible provision of spawning habitat. Kijin Nam has been doing a lot of the modeling, and our work on this case was to provide design velocities for several restoration configurations and to estimate salinity impacts over a 1-2 year period. We are currently examining the designs in combination with various other marsh restoration projects. A feasibility study including the design elements is in progress, and expected to be released in late 2017.

Our second Smelt Resiliency project analyzes the effect of submerged aquatic vegetation (SAV) removal. The potential benefits to smelt include influences on residence time, turbidity and food. The SAV removal project is an interagency effort being managed by DWR Department of Environmental Services. The current scope is a field experiment comparing two islands in the Liberty Island/Cache Complex. One (Little Hastings) is being treated with herbicide, the other is treated as a control group -- in fact one of the first modeling efforts was a high resolution particle study to confirm the choice of treatment and control so that the herbicide would be less likely to reach the control island. With VIMS, we've already completed a SCHISM module for SAV (see below). Eli Ateljevich has done some of the work on residence time and Nicole Cai, a graduate student at VIMS, has begun modeling temperature and water quality. Our goal through both monitoring and modeling is to describe how temperature, flow and water quality is affected by vegetation density in the two islands.

Farther south in Clifton Court Forebay (CCF), we are working on another round of modeling following up our report entitled Clifton Court Dredging and Transit Time Analysis. The original report by Qiang Shu and Eli Ateljevich was instigated under the 2009 NMFS Biological Opinion, which mandated an investigation of how bathymetry manipulations such as scour and fill might affect mean flow transit time of salmonids through CCF. The premise, confirmed by recent field work, is that reducing transit time through the Forebay benefits fish by reducing predation and other risks. A validation of our flow modeling is included in the Report and indicates a good ability to reproduce observed velocities, although we noted in the report historical velocity data are incomplete during windy periods. Our main transit time result in the bathymetry project was that interventions such as a dredge between the radial gates and Banks intake channel do indeed reduce transit time; however, the increment is small compared to differences arising from flow management.

Our follow-on to the Clifton Court study has two components. First, the Delta Conveyance Branch and collaborators are developing a bioenergetics survival model for CCF and using it to fit fish tracking data collected in the first half of 2017. One ingredient is transit time, for which we are substituting particle transit time under mean flow as an estimate. Second, we will be looking at operational changes to see the potential of using alternate operations such as larger flows less often – and ultimately considering how these results can be connected to the larger system.

The possible benefits of this project come from preventing entrainment through False River tidal exchange with the main conveyance corridor, food production, reduction of predator habitat, and possible provision of spawning habitat.

Finally, Rueen-fang Wang continues to work from last winter modeling flows exiting the lower Yolo Bypass. which models from roughly Lisbon Weir down. We are attempting to apportion flow between the various outlets of Yolo bypass onto Liberty Island particularly in the area of the “Stairstep” (see Figure 1). We have also done two aerial reconnaissance trips to support this effort in low and high flows, as well as collating satellite and aerial shots from other researchers.

What we have found in our Yolo work is that the channelized outlets (Shag Slough, Liberty Cut, Toe Drain) have a substantial capacity to move flow off the Bypass – perhaps 30,000 - 50,000cfs. Flow must be around 200,000cfs (15 ft stage at the Stairstep) before it all goes under water which is a fairly rare flow. Our previous rule of thumb that the Toe Drain has 3000 cfs of conveyance still applies to overtopping at Lisbon, but the Toe Drain carries probably three times this figure below the Stairstep even as it overtops in places, and leakage through the northern levees above the Stairstep is conveyed out by the three channels. As waters rise, we see first a leakage to Liberty Cut, then flow onto Holland Cut and then a direct connectivity between the main bypass and Shag Slough. These pathways are all active in Figure 2. Direct flow over the whole Stairstep is more rare because the levees lining the southern part of the channel are higher. Based on stage records, we would expect full overtopping to occur only during peaks in exceptional years – for instance, 2017. The exact flow routing is still a mystery because of bathymetry uncertainty in vegetation and the difficulty of interpreting aerial photography. Nevertheless, the patterns described here seem to match photography well.

Model Development

Our featured development for this newsletter is the submerged aquatic vegetation module (SAV) for SCHISM. Increasing vegetation during the drought and the Delta Smelt Resiliency Strategy have brought more attention to the role of submerged aquatic vegetation (SAV) in controlling flow and conveyance, altering sediment deposition patterns, changing water quality (particularly dissolved oxygen and temperature) and providing predator habitat for smelt.

Vegetation has numerous effects of flow. It produces drag within the canopy, contributes to turbulence production and suppresses wind waves. A challenge in modeling vegetation is that flow develops sharp velocity shear between the canopy and free flow. Such shear develops laterally as well as vertically. The shear, particularly vertical shear, is difficult to model while retaining the stability and robustness benefits of a semi-implicit model. Our formulation adds some assumptions about turbulent shear stress, which allows us to incorporate it along with drag into the implicit, highly stable part of our calculation. We've been able to replicate complex flows from laboratory experiments and these in turn help us match qualitatively the flow characteristics user group member Deanna Sereno noted in her modeling and field work in Franks Tract such as eddies limited by a "wall" of Egeria Densa. A manuscript on this development is nearing completion.

An example of what the SAV module can do is shown in Figure 3 which shows how ebb tide velocity in Franks Tract is channelized with vegetation (lower plot) compared to the corresponding case without it (upper plot). Note how ebb flows are channelized more compared to the more classic radial pattern from the vegetated case. Dissipation from the vegetation also changes local tide propagation paths, allowing 5% or so higher tidal range of flow in the eastern remnant channels south of the Old River station OSJ) – see the white oval in Figure 1. The increase in tidal range at OSJ occurs because the San Joaquin is now a path of less resistance and, more subtly, because the tide at OSJ is the resultant of tidal propagation clockwise from the San Joaquin and counterclockwise from Franks Tract and this "opposing" path through Franks Tract is is now dissipated. The main challenge at the moment is parameterizing the vegetation in the model so that it is plausible at least in a statistical sense – including heterogeneity. We have found images of normalized difference vegetation index (NDVI) capture the presence/absence patterns of communities well, but not density which is highly variable. Furthermore, the appropriate level of aggregation of the drag elements (leaf? stem? plant?) is still an issue widely discussed in the literature.

Publication

Besides the Clifton Court report, we've developed several manuscripts and made several presentations in the past six months. With our collaborators in the

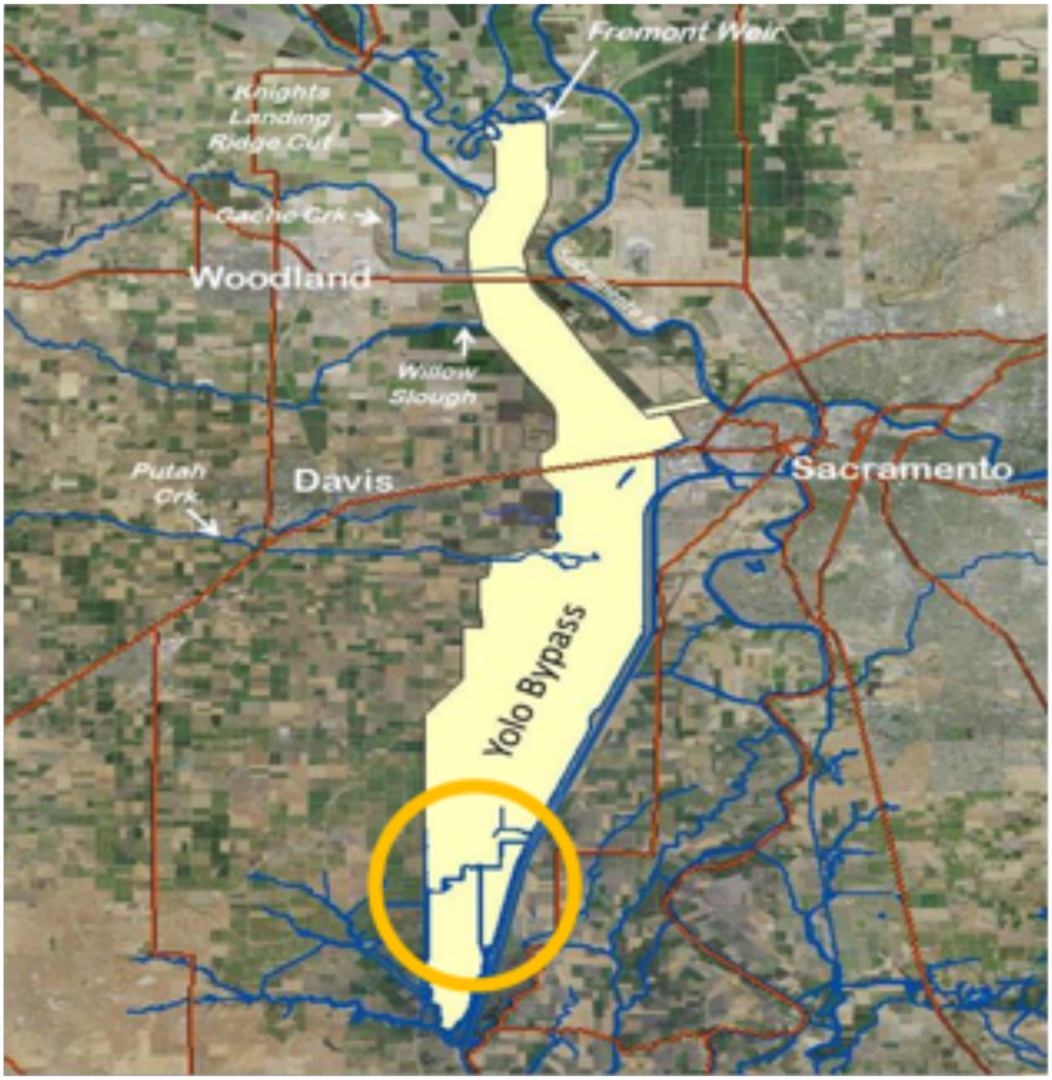


Figure 1: Yolo Bypass with the locaiton of the Stairsteps circled.

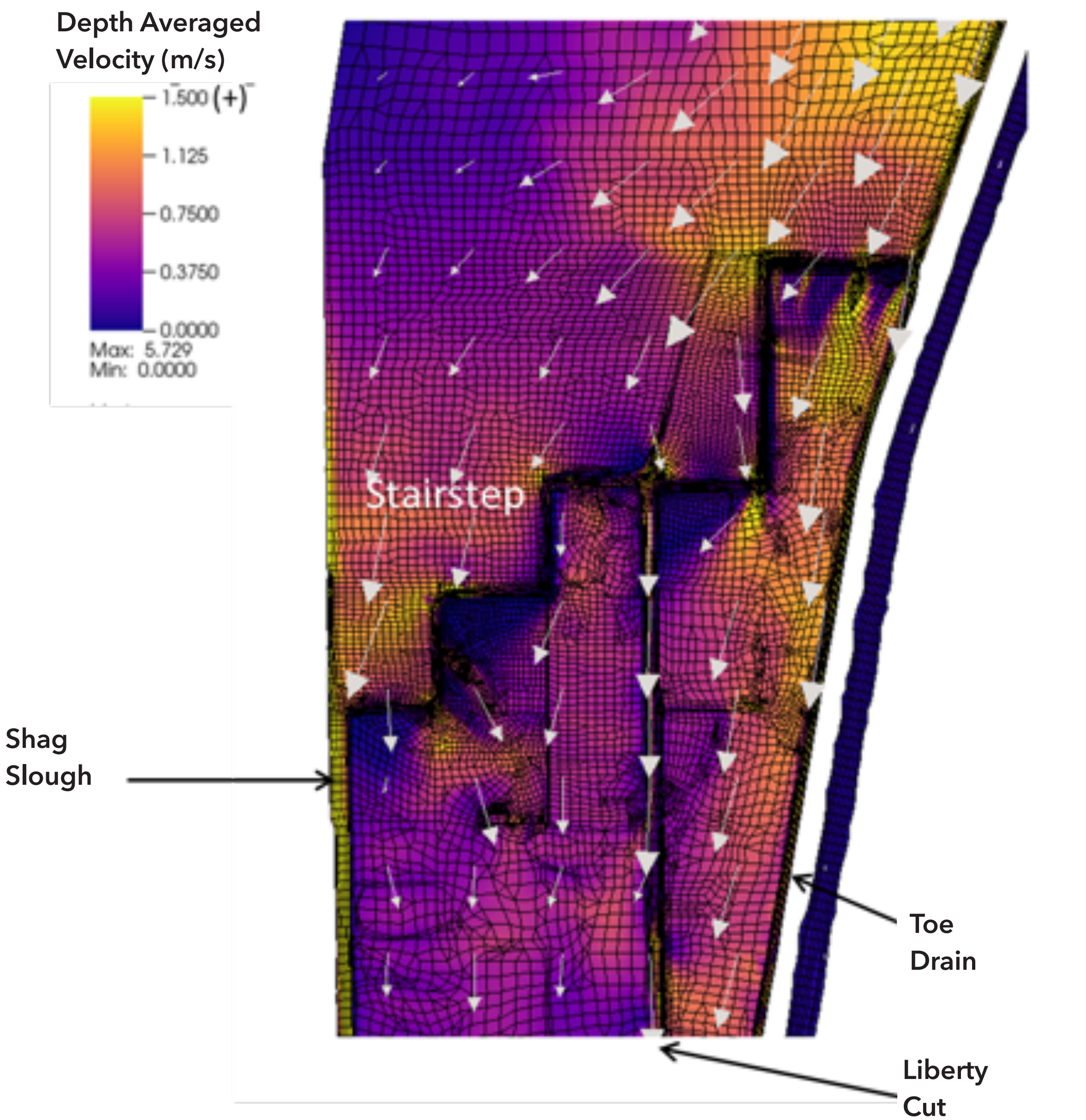


Figure 2:
Velocity magnitude (color) and direction (arrows) during the peak of the Yolo Flood.

NASA-HYCO project (main author Yi Chao) a manuscript has been accepted for publication by Journal of Geophysical Research (Ocean) that describes temperature validation and modeling of the recent anomaly using our Bay SCHISM model coupled to ROMS. Lastly, at this years IMUM conference at Stanford Joseph Zhang presented on the SAV module (described above) and Eli Ateljevich presented results concerning the vertical grid that will be incorporated in future work for moderate sea level rise.

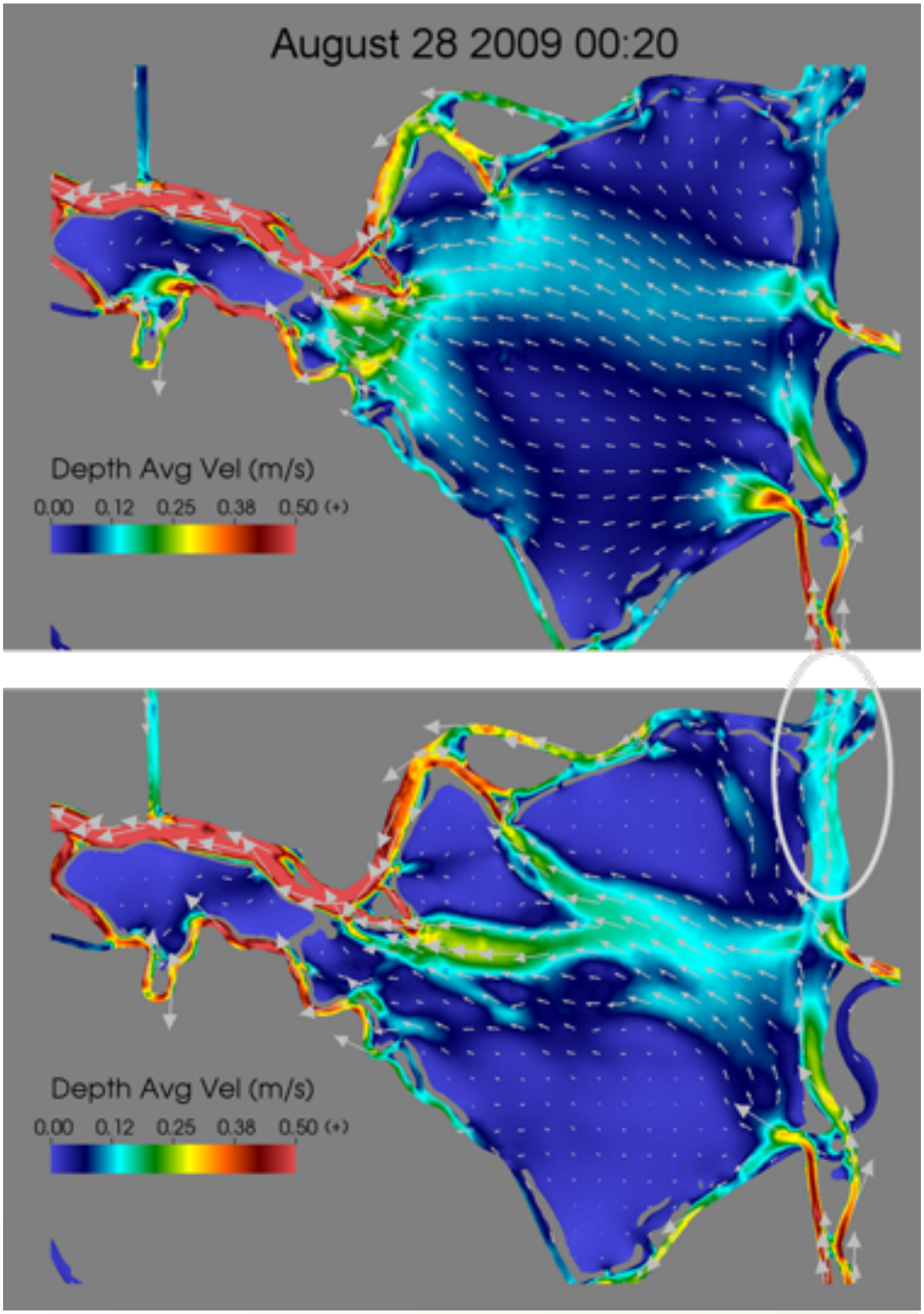
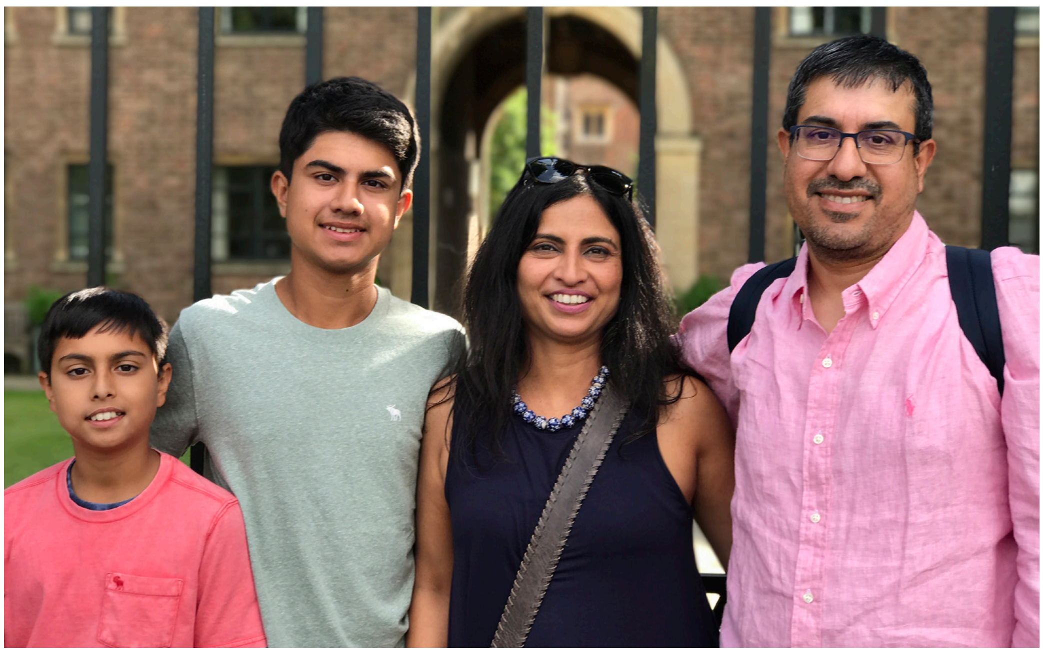


Figure 3: Ebb velocities in Franks Tract wihout (above) and with (below) vegetation. White oval is the eastern channel coming in from the San Joaquin past CDEC station OSJ.

20 Things You Don't Know About Me . . .

Nicky Sandhu



Visiting Cambridge, England this summer.

Nicky, a Supervising Engineer and new Chief of the Delta Modeling Section, revealed to DMUG with 20 fun facts you may not know about him.

(For Nicky's very first interview with the Newsletter published back in 2008, please check out: [http://baydeltaoffice.water.ca.gov/modeling/delta-modeling/DSM2UsersGroup/DSM2UG-5.pdf](http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/DSM2UsersGroup/DSM2UG-5.pdf))

1. *My very first job was delivering newspapers in bulk on a truck to those who make the delivery rounds and then checking up on them.*
2. *When I was in college, I liked to play table tennis and a game called Carroms.*
3. *I went into the engineering field because I believed I was good at math and lousy at remembering things. I could derive things from basic principles and so engineering seemed like a good match.*

Walking near Tower Bridge in London.

4. *My first job with DWR was as an Assistant Engineer. However my very first job with the state was as a permanent intermittent employee at California Department of Conservation in their Earthquake Monitoring section. I digitized seismographic sensors.*

5. *My first assignment as an engineer at DWR was to use Artificial Neural Networks (ANNs) to model flow-salinity relationships in the Delta.*

6. *I have been with DWR for a total of 17 years. I did for a while work in IT for the private sector before coming back to DWR.*

7. *If I didn't go into the engineering field, I would have studied economics.*

8. *In college, my favorite classes were Political Science and Macro Economics.*

9. *My first car was a Honda Accord.*

10. *I live in Davis with my family. I love the community atmosphere and the bike paths.*

11. *My favorite color is blue.*

12. *My favorite snack is pistachios.*

13. *I love Thai food!*

14. *My ideal vacation is lying under the stars in a hammock…ideally near the ocean.*

15. *I don't watch TV anymore…I only Youtube or Netflix. I am watching Sherlock Holmes these days.*

16. *My poodle's name is Denali.*

17. *I love wine. I like 'em cheap and sweet.*

18. *The most important person(s) in my life are my kids. Of course, unless I am being asked by my wife… :)*

19. *My favorite time of the year is spring. Everything feels like it's getting a new start.*

20. *So far, my favorite part (or most challenging part) of being Chief of the Delta Modeling Section is doing this interview.*

A Meandering Path – Anne Huber's Story

Min Yu, Senior Engineer WR, DWR
Anne Huber, Water Resources Analyst, ICF

Anne is a veteran of our modeling community. Her specialty is assessing and documenting project effects on water resources by evaluating hydrology, water quality, and habitat suitability in rivers, reservoirs, and the Sacramento-San Joaquin Delta. Anne has been with the DSM2 User Group since the very beginning. While she may at first appear quiet and reserved, her warm and friendly personality is familiar to all who know her. It is easy for people including myself to consider Anne a sidekick of Dr. Russ Brown at ICF, only to discover that Anne is far from it, and is in fact a wonder of her own.

Anne was born and raised in Carlisle (pronounced as CAR-lile), Massachusetts, a small town northwest of Boston. After graduating from Concord-Carlisle High School (which has school mascots of either the Patriots or Grapes, depending on the sport), she attended MIT for her BS in biology. Biology research and classes at MIT are primarily molecular and cellular in nature, but between her Junior and Senior years at MIT, Anne took an opportunity to do ecological field work on Barro Colorado Island in Panama, which made her wonder if she would prefer to work outdoors rather than in a lab.

Anne's first job after obtaining her BS degree was working at the biotech company Advanced Magnetics in Cambridge as a research assistant. According to Anne, the company's primary effort at the time was to develop a mixture of magnetic particles and antibodies for imaging purposes. Her own particular work, however, was the development of radioimmunoassay kits. Lab work was interesting, but Anne wanted to try more macro biology, so while at Advanced Magnetics, Anne started looking for a university to pursue a master's degree in ecology. She visited many colleges, and eventually fell in love with UC Davis, since UCD has a good ecology program and is located in the small-town environment Anne enjoys.

Anne moved to California to attend UCD in 1987. The subject of Anne's graduate project was the mosquito Culex tarsalis. She confesses to making the mistake of choosing a topic of research that

Anne and her husband John, west of Davis.

resulted in studying two strains of mosquitos raised in a basement instead of working in the great outdoors. The topic was interesting, however, and involved comparing the ability of the two strains to transmit encephalitis based on their life history. One of her tasks was to develop a life cycle model using FORTRAN, which turned out to be pivotal for her future career in the water resources modeling field.

Anne met her husband John during her graduate program. John was also a UCD graduate student, studying mechanical engineering at the time. Partly because of John, Anne stayed in California instead of moving back East after graduation. After finishing her Master's degree in Ecology in 1990 from UCD, Anne was ready to broaden her horizon and take on more challenges. She quickly found a job as an environmental specialist and ecological modeler with BioSystems Analysis in Tiburon, Marin County. The flexibility to explore and work on a variety of projects was exactly what Anne was seeking. Her initial work at BioSystems involved looking for special-status invertebrates, but she soon delved into numerical modeling, running a Chinook salmon population model (CPOP) and USBR's water operations model (PROSIM).

BioSystems experienced a downturn in 1994 and eventually went bankrupt, so Anne went job hunting again. She was hired by Jones & Stokes Associates (now part of ICF) in Sacramento as an Environmental Specialist. Anne's career took off as she furthered her experience by working on a wide range of projects. Anne's modeling experiences at ICF first focused on temperature and dissolved oxygen modeling, then other hydrology and water quality modeling in past years. Most recently she has mainly concentrated on quantitative assessment and EIR/EIS documentation. She is adept at data analytics, model applications and development, having worked extensively with a variety of models including multiple temperature models, DSM2, CE-QUAL-W2, MIKE 11, and fish population and habitat spreadsheet models.

Anne is now working as a Water Resources Analyst/Technical Specialist. Anne emphasizes the key characteristic of her projects as being 'variable.' Her current main responsibilities are to interpret and post-process other people's modeling results, report on findings, and integrate with other resources. Her latest project is a major effort collaborating with many people on the SWRCB Bay-Delta Plan Amendments.

Anne's son William and Anne at Hoover Dam.

The number of projects that Anne has worked on seems countless. Some of the major ones were Guadalupe River temperature modeling, Delta smelt population studies, Walker Lake restoration, Caltrans US 101 Willits Bypass water quality studies, and multiple Delta salinity and water quality projects. Upon reflection on her work experiences, Anne finds that compared to population modeling, water resources modeling is more straightforward and better able to produce results that match measurements.

Looking back through her 23 years of working at ICF, Anne's favorite projects have been ones that involved both data collection and running a model using the data she gathered. As an example, for the Stockton Deep Water Ship Channel (SDWSC) project for CALFED, Anne and a coworker were tasked to drive a motorboat around the Delta to measure electrical conductivity in the area of the SDWSC and to use the collected data and DSM2 to assess tidal exchange, net flows, and the mixing of Sacramento and San Joaquin River water in the Delta.

No matter how fulfilling her career has been, Anne seems also to get enjoyment from her family life. Along with husband John who has many interests in aerospace, transportation, and renewable energy, Anne has a creative son William, who's currently studying electrical engineering at UCLA. I could tell from Anne's voice when we chatted about William that he is certainly Anne's pride and joy. Anne recalled an incident when William

New Hampshire, note blueberries in background.

was about 10 year's old. She bought him a book on electronics from RadioShack. The next day after work, just when Anne was ready to start to go over it with William, she found that he had already finished one third and was immensely enjoying reading it. During his junior year in high school, it didn't take any coercion from Anne to get him to make a remote controlled water sampling boat for Anne and coworkers to use for a project. "He was born an engineer," Anne quipped.

Outside of work, the family is into bicycle riding. Anne usually bikes several times a week, mostly in Yolo, Sacramento, Solano, and Napa Counties, including biking to work one round trip per week. Trips farther afield include recent rides in New Hampshire, the Bay Area, and a long weekend trip to Etna California with the Davis Bike Club.

Anne's passion for life shows in a creative side she expresses through photography. This hobby was influenced by her mother who is a photographer for a local newspaper in Massachusetts. Anne's favorite subject for photography is the outdoors and nature. Anne also enjoys seeing and doing new things through travel. Her most recent family trip was to Idaho in August to see the total eclipse. Over the past year, she and John have been traveling more frequently to southern California to visit William. Let her know if you have any recommendations for good unusual destinations down there.

Fremont Weir.

From East to West – Siqing Liu's Story

Min Yu, Senior Engineer WR, DWR

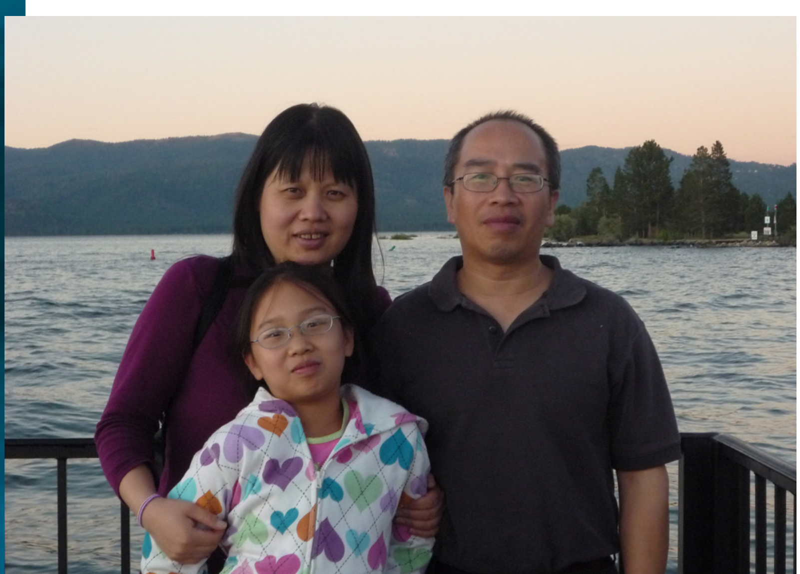
Siqing has been with DWR for almost ten years. He started with the Delta Modeling Section in the Bay-Delta Office in 2008, and then moved to the Operations Control Office in Division of Operations and Maintenance (O&M) in 2015. For folks who aren't very familiar with Siqing, he has presented two talks at DSM2 User Group meetings: Aqueduct Model Validation for Hydraulics, EC, and Bromide in 2011, and Animation of DSM2 Outputs in ArcMap in 2015. To call Siqing low-profile and humble is an understatement, so to fully appreciate his background and accomplishments you have to read between the lines.

Siqing was born in a small town in Hubei province, China. He attended Huazhong University of Science and Technology, one of the top Chinese technology schools. Admission to this university in Wuhan was fiercely competitive, particularly for students coming from rural places. Siqing doesn't elaborate much on his educational journey, but it must have been arduous. He studied Mechanical Engineering from 1984 to 1988 for his undergraduate program. After graduation, Siqing moved to Beijing and attended China Agricultural University to pursue his Master's Degree in Civil Engineering. Upon graduation, he was hired as a lecturer to teach at the same university. Obtaining the position of a university lecturer in China was another highly competitive process.

In 1998, Siqing headed to USA to study abroad for his PhD program. His first stop was Utah State University in Logan. Siqing spent one year in the groundwater resources PhD program under the Biological/Agriculture Irrigation Engineering Department. His specialty was Groundwater Hydrology. In 1999, he transferred to Gainesville, Florida to continue his PhD program at the University of Florida. His focus was hydrologic science including groundwater and surface water hydrology. He also worked as a Research Assistant, studying the interaction between surface water and ground water. The project required him to develop a statistical tool for evaluating the effect of the variability of surface roughness (through Manning's Coefficient) and subsurface hydraulic conductivity on surface runoff and infiltration. After completing his PhD program, he began his post-doctoral fellowship at University of Connecticut from 2003 to 2005. For those 18 months, Siqing was busy and productive as he: 1) modified a 2-D USACE Gridded Surface/Subsurface Hydrologic Analysis (GSSHA) model; 2) re-wrote the GSSHA source code related to channel flow modeling to reflect the change in the spatial representation of channel network introduced with vector channel descriptions and then integrated a surface water model with the GSSHA model; and 3) developed a soil erosion and sediment transport model and integrated it with GSSHA and then calibrated the model with a new representation of the channel network.

In 2005 after finishing his postdoc, Siqing returned to Florida to work as an Environmental Engineer for Ecology and Environmental Inc., a consulting firm in West Palm Beach. His main responsibilities were model development and enhancement, as well as creating tools related to groundwater modeling. A few examples of his projects include the development of a Lower East Coast Sub-regional (LECsR) model application template using Python, MODFLOW source code modification to generate a daily flow budget for user-specified zones, using JAVA to create post-processing tools for plotting a variety of statistics analysis charts, and the development of a numerical model based on MODFLOW for Windows (PMWIN) to simulate groundwater flow and mercury transport.

After three years working and living in the Sunshine State, Siqing was convinced by his friends in California to consider moving west. Siqing had been aware of the water issues in California and had been interested in DWR and its modeling group for some time. He believed his background could be a very good fit. With a job lead from his DWR friend, Siqing decided to give it a try and applied for the vacant position in Delta Modeling under Bob Suits. The hiring process took three interviews, which for Siqing were by phone, in order to reconcile his humility with his accomplishments, which were clearly exceptional.



Lake Tahoe

Point Lobos

Siqing with his wife Cao Dong and daughter Erica

Siqing moved to Sacramento in fall 2008 to begin his career with DWR where he was the Delta Modeling Section's key support for the DWR's MWQI program. He also developed various tools for data analyses, model performance assessment, and visualization. He improved the DSM2 extension for the California Aqueduct model and collaborated with O&M in improving short/long-term forecasting of hydrodynamics and water quality in the Delta.

Siqing mentions that one of his most interesting projects was to providing the technical support for the North Delta ligation team. He conducted modeling studies to compare stages and velocities in order to evaluate sedimentation potential in north Delta under long-term operation of the Delta Cross Channel. Siqing felt that the study allowed him to apply his technical skills to an actual situation and he was able to contribute to a successful outcome. The other important project for Siqing was the drought barriers study in 2009. DWR's South Delta program requested an assessment of proposed drought barriers' potential impacts on stages in the Delta. Siqing generated an effective GIS animation tool to show changes in stages with and without the drought barriers.

In March 2015, Siqing moved to the Operations Control Office in O&M (On a side note, while I was happy for Siqing, his leaving felt like a huge loss on my part since he was one of my go-to guys for responding to outside inquiries on historical simulations and meeting any PYTHON scripting requests. Time heals all wounds, they say. After two years, I've grudgingly accepted

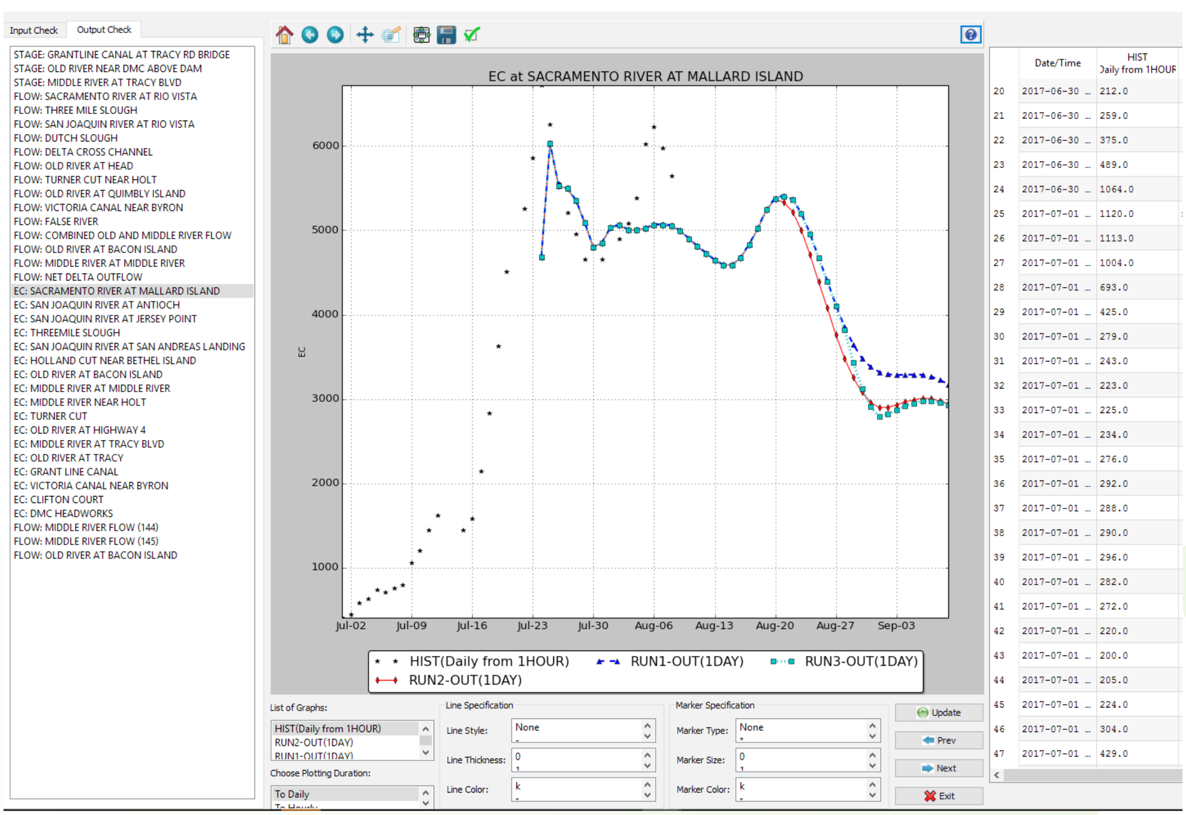
Crater Lake

the fact :-)). When I recently asked Siqing what was the motive for his moving, he revealed that the job itself in O&M in fact had a similar scope of work as what he did before. However, one change was that his current job allows him to better appreciate the bigger picture and how the parts lead to the whole. He now feels he has a better understanding of how the tools he has developed are applied and the needs for further improvements.

Siqing has been working on revamping the tools for near-term forecasting, seasonal forecasting, and historical simulations of Delta and Aqueduct water quality. He has simplified and refined the process for unifying three tools into one through a GUI which also gives users the choices on making selections and changes. He reports two very exciting projects the last two years. The first was the development of a GUI using PYTHON programming to download hydrological and water quality data from CDEC and then allow users to interactively QA/QC downloaded raw data from CDEC. What makes this tool 'revolutionary' is that it allows users to download a set of 200 groups of observed data including EC, DOC, Bromide, and Turbidity at locations all over the Delta and simultaneously QA/QC several datasets, all in one shot. The entire process only takes 20 minutes to complete. The second 'gem' in Siqing's toolbox is a standalone PYTHON program called 'Delta Data Analyzer' (see the screenshot attached) that he developed in 2016. The program provides users an opportunity to uncover reasons for any red-flagged output data after a model run. The focus of this program is to compare the model output with the historical observed data and its associated input data being verified so that any errors in the input data could be captured.

Outside work, Siqing has a very fulfilling family life. Siqing and his family live in Carmichael. He met his wife Cao Dong at China Agricultural University, where she was Siqing's professor's daughter. Cao Dong has also been working for the CalFire as a senior accounting officer. They have a 15 year old daughter Erica, who is a gifted student attending the International Baccalaureate program at Mira Loma. The family likes camping and traveling and appreciates places with beautiful scenery. Furthermore, Siqing enjoys his new hobby of photography in his spare time. He has been taking lessons at American River College in the evenings the last two years. He recently finished Portrait Photography and is ready to take his next step in Advanced Digital Photography. When I asked him if he could share any of his masterpieces portraits, Siqing only responded with "um", "uh", and a shy chuckle after saying "Those are not good enough; maybe next year." Well, knowing Siqing and his usual low-key and humble self, I am certain they are as amazing as any of the work he has touched.

Delta Data Analyzer



If You Have the Questions, We Have the Answers!

Q: I'm writing to see if you can help us locate some data related to cross Delta (XGEO) flow. Specifically, we are interested in the following:

1) Measured flow data at the DCC and Georgiana Slough that were used to calibrate the DAYFLOW equations for XGEO. According to the DAYFLOW documentation, these data were collected in October 1979.

2) Historical DCC gate operations associated with the data collected during October 1979.

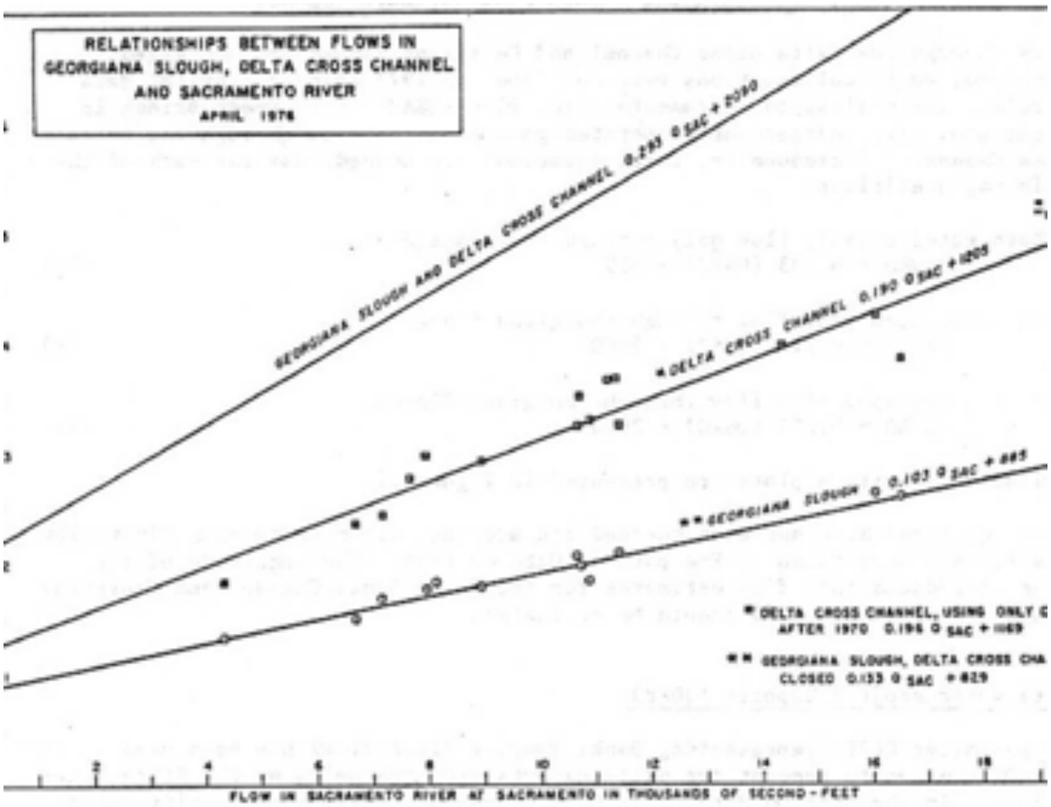
3) Measured flow data at the DCC and Georgiana Slough that have been collected beginning WY 2003, along with historical DCC gate operations during the same period. According to DAYFLOW documentation, XGEO values beginning WY2003 are based on measurements, so they are available somewhere.

Paul Hutton, Principal Engineer, Tetra Tech

A: *Please see the responses below–*

1) For the data that was used in 1978 to generate the regressions posted in DAYFLOW, I assume the data was the same as shown in the graph of the regressions, dated April 1978, as part of DAYFLOW documentation. This graph is freely available at: http://www.water.ca.gov/dayflow/documentation/fig4.cfm

The graph doesn't specify whether the data reflect some averaging. The range of Sacramento flows in the graph is rather limited. A footnote on the Delta Cross Channel curve refers to the regression being based only on data after 1970. I suspect the data reflect multiple old tide cycle runs in which a boat crew went along a strung tagline measuring velocity. Prior to the mid 1980s, these would be done from time to time over 1 or 2 days at selected sites for various reasons.



2) Please download the historical DCC gate log table from 1953 to 1984 in PDF format at: http://dsm2ug.water.ca.gov/library/-/document_library/view/429273

3) Please download the dss file at: http://dsm2ug.water.ca.gov/library/-/document_library/view/429249/1203

   The file was created by Lan Liang from the CDEC data. Flow in the Delta Cross Channel and Georgiana Slough is measured and collected by USGS. This data is freely available starting in September 2003 via CDEC. The stations names are DLC and GSS. Any errors in the data are nearly always quite obvious.

Answer provided by Bob Suits, Senior Engineer WR, DWR and
Aaron Miller, Supervising Engineer WR, DWR

Q: I was trying to read the DSM2 HYDRO tide files in MATLAB. But the new format DSM2 tide files use HDF5 with szip compression. MATLAB doesn't support szip compression. HDF5 suggested that I repack the DSM2 tide files using HDF5_ repack and then open in MATLAB. I would like to try this. Any suggestions?

Vamsi Krishna Sridharan, Assistant Project Scientist,
University of California, Santa Cruz

A: The DSM2 HYDRO tidefile has always used the szip compression. This is also true for the DSM2 QUAL tidefile as well.

We don't use MATLAB internally and have no experience in writing interfaces to it.

I think your idea is fine in terms of using HDF5 tooling to repack the DSM2 tidefile. However if you are looking for extract time series from the tidefile into DSS, the current version of VISTA allows a user to open a tidefile and extract the data into time series data.

However that will not help if you want to stick with HDF5 data as is.

Answer provided by Nicky Sandhu, Supervising Engineer WR, DWR

Q: I have a question about the DSM2 grid version. We have a life cycle model that was based on the grid version 2.0 (2002). Is there an updated version since 2002? If so, what is the version?

Li-Ming (Lee) He, Modeling and Adaptive Management Division Chief,
U.S. Fish and Wildlife Service

A: We don't have a newer map of the grid, but DSM2 Version 8.1.2 released in November 2013 is our latest release with the NAVD88 datum. There have been some modifications for a few channel lengths as well.

Answer provided by Lianwu Liu, Engineer WR, DWR

If you have any questions or comments regarding this issue of the Newsletter, please contact the facilitator of the Delta Modeling User Group:

Min Yu, P.E.,
Senior Engineer WR
Delta Modeling Section
Bay-Delta Office
Min.Yu@water.ca.gov
916.653.5225

California
Department of
Water Resources
1416 9th Street
Sacramento, CA 95814

This newsletter can be accessed at the Delta Modeling User Group website:
http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/dsm2usersgroup.cfm